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THE DIGEST

OF

PHYSICAL TESTS

AND

LABORATORY PRACTICE.

A RÉSUMÉ OF PRACTICAL TESTS MADE IN THE LABORATORIES OF THE WORLD.

JOSEPH W. BRAMWELL, EDITOR.

VOL. II—1897.

PUBLISHED QUARTERLY BY
FREDERICK A. RIEHLÉ,
NO. 1424 NORTH NINTH STREET,
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Digest of Physical Tests, 1897.

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JOSEPH W. BRAMWELL, EDITOR.

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Records elastic curve up to Yield-Point on a magnified scale, thereafter on natural scale.

Is applicable to all shapes of test-pieces with equal accuracy and readiness.

Is equally applicable to wire, and also fine strips.

Records compression as well as tension and alternate stresses.

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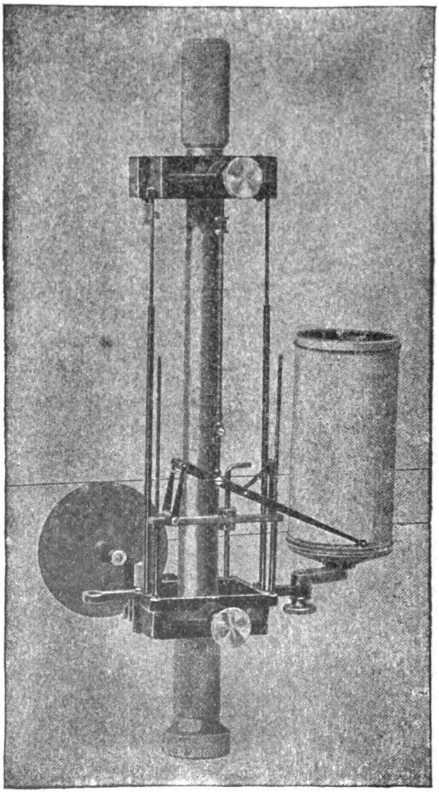

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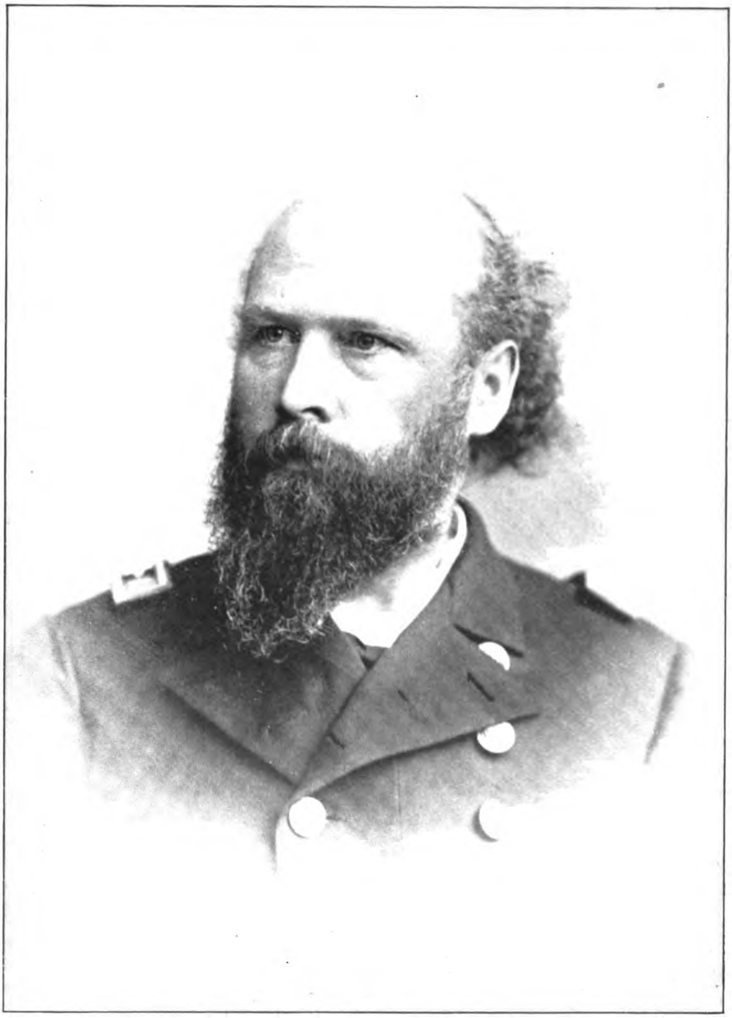


Geo W Melville
Engineer in Chief U.S.N.

Digest of Physical Tests.

A RÉSUMÉ OF PRACTICAL TESTS MADE IN THE
LABORATORIES OF THE WORLD.

Vol. II. **JANUARY, 1897.** **No. 1.**

GEORGE WALLACE MELVILLE.

By Frederick A. Riehlé.

THE subject for our frontispiece of this, the January number of THE DIGEST OF PHYSICAL TESTS, is well known to most of our readers, and needs no introduction. George Wallace Melville, Engineer-in-Chief of the United States Navy and Chief of the Bureau of Steam Engineering, was born in the city of New York, January 10th, 1841. He traces his ancestry far back to noble Scottish lineage. He attended the public schools of New York City, particularly Grammar School No. 3, then the Christian Brothers' and Polytechnic School, of Brooklyn, N. Y. About 1860 he completed his term of apprenticeship in the mechanical trades with James Binns' East Brooklyn Machine works, Brooklyn, N. Y. In July, 1861, he received an appointment as Third Assistant Engineer in the Navy of the United States, and served throughout the war in Governmental service, and has continued in the same to the present date.

Mr. Melville has advanced step by step through almost every grade, and has now attained the highest position in the Navy Department. His last promotion secured him the high rank of Commodore.

We enumerate below some of the official positions Mr. Melville has held, showing this distinguished and eminent engineer's busy and eventful career. In 1870 Mr. Melville occupied an important Brazilian station; then a short cruise was made by him to the Arctic in the "Tigress;" this was in connection with Hall's Relief Expedition; then a trip to China and Japan and the East Indies until 1878. In April, 1879, he joined the "Jeannette" Arctic expedition, sailing for the Arctic region July, 1879. The success of this expedition was mainly due to the intelligent and painstaking equipment of the vessels, especially the judicious selection of all the various articles of clothing, diet, etc., etc., to which Mr. Melville gave his personal supervision in every detail.

The history of this expedition is well known by every reader who has been entertained and startled by the perilous adventures of the brave men who passed several years of their lives within the Arctic Circle. This first expedition occupied from 1879 until June 12th, 1882. The "Jeannette" was crushed in the ice, and the explorers were obliged to abandon it and escape on sledges, and finally returned to New York on September 13th, 1882. In 1883 he was a member of Greely Relief Expedition and rendered efficient service in fitting out and serving on the "Thetis" of the Relief squadron.

In 1886 we find this engineer on duty at Messrs. Cramp Ship Yard, Philadelphia. In 1887 he received the appointment of Chief of Bureau of Steam Engineering and Engineer-in-Chief of the Navy, which position he has held ever since. His present term of duty will expire January 16th, 1899. Under existing law the Commodore will retire from active service January 10th, 1903.

Scarcely any official in the U. S. Government service has been the recipient of as many titles and decorations as Commodore Melville. They are almost too numerous to mention; among the most prominent might be noticed the following:

Doctor of Engineering; E. D. Degree conferred by Stevens Institute, Hoboken, N. J.; Gold Medalist by Act of Congress of the United States, and promoted fifteen numbers for heroic and meritorious service in the Arctic; Honorary member of Society of Naval Architects of Great Britain; Honorary member Society Anthropology and Geography, Sweden; Member of National Geographical Society of the United States; also of the Geographical Club of Philadelphia; Military Order of Loyal Legion; Grand Army of the Republic; Naval Order of the United States; Society of Mechanical Engineers of the United States; Naval Architects and Marine Engineers of the United States.

It is not the intention of the writer, nor is it necessary to attempt to add any praise to or enlarge upon the merits of our distinguished countryman. Too often indeed it is the case, after their decease, to honor those whose incessant application in their calling has elevated them to the highest positions. Instances can be recalled of conspicuous examples of sad neglect, and unrequited reward, as the only returns of heroic service; nor is this peculiar only to the United States. It therefore affords us pleasure to note the many expressions of esteem and admiration already tendered the subject of this article, and we desire to emphasize this fact. We wish Commodore George Wallace Melville a continuation of that which he has so rightly earned by his labors—success.

LONGITUDINAL VS. TRANSVERSE STRENGTH OF STEEL PLATE.

By Prof. C. H. Benjamin, Case School of Applied Science, Cleveland, O.

IN building the ordinary forms of steel boilers it has been the custom formerly to run the plates around the shell instead of lengthwise, thus bringing the longitudinal strength of the plate in the direction of the greatest fibre stress. With the introduction of steel in place of iron as a material for boiler shells, this arrangement has been done away with to a large extent and the lower half of the shell has been made of one steel plate running lengthwise of the boiler, with no ring seams over the fire to cause trouble by scale and overheating.

This has been done on the assumption that steel plate, being homogeneous in texture and not fibrous, has the same strength in either direction. Although the truth of this assumption is pretty generally recognized by steel manufacturers, some makers and users of boilers have been rather skeptical on the subject, and the writer has not seen much definite information published in regard to it. The experiments to be described were made under the direction of the writer in the mechanical laboratory of the Case School of Applied Science by Mr. R. B. Kernohan as a part of his graduating thesis.

Four pieces of steel boiler plate, each 30x16x⅜ inches, were purchased from the manufacturers, two from the Otis Steel Company of Cleveland, and two from the Parke Bros. Company of Pittsburg, one piece being flange and one marine steel in each case.

The direction of rolling was ascertained and marked on each plate. As there is no desire to compare the products of the two firms mentioned, the names will be omitted in describing the tests. The plates were marked off, numbered, and finally sheared in the manner shown clearly by Fig. 1. The test-pieces were made from these strips by milling to the standard shape of tension specimens for flat plate, with a distance of eight inches between marks.

Mr. Kernohan made careful analysis of samples from each plate, determining the carbon, sulphur, phosphorus, and manganese.

The specimens were all tested for tensile strength and ductility in a Riehlé 60,000 lb. testing machine owned by the school. Autographic diagrams of the elongation were made by the use of a new recording extensometer devised by the writer and shown in Fig. 2; from these the elastic limit and modulus of elasticity were determined.

Tables 1 to 4 show the results calculated from the experiments, the numbers referring to the marks on the specimens, as shown in Fig. 1. These tables explain themselves, and it is only necessary to say that the elastic limit in each case was determined by inspection of the characteristic curve drawn by the extensometer, and that as this line is a curve of gradually increasing curvature from the origin to the elastic limit (see Fig. 3) there is no constant value of the modulus E. The first value in each case is calculated from the elongation at the elastic limit, and the second value from the elongation at one-half the elastic limit. The latter value corresponds quite closely to what would be obtained by using the tangent to the curve at the origin. A careful study of the tables will convince any one that there is practically no difference in their main characteristics between the longitudinal and the transverse strips. The differences between consecutive pieces from the same set are often greater than the differences between averages of the two sets.

The specimens Nos. 43 to 48 were of uneven thickness, and consequently broke near one end. This made any calculation of the percentage of elongation impossible and rendered the values for contraction and for unit stress somewhat uncertain. With these exceptions the experiments can be relied upon.

As the extensometer used in these experiments is of a new pattern designed by the writer, and this is the first extended use that has been made of it, a brief description of the instrument will be given.

TABLE I.—NO. 1 FLANGE STEEL.

	No.	Contraction, Per Cent.	Elongation, Per Cent.	Stress at Elastic Limit.	Ultimate Stress.	Modulus of Elasticity.	
						At Elastic Limit.	At One-half Elastic Limit.
Longitudinal.	1	43.1	26.3	34,980	58,290	18,170,000	38,160,000
	2	46.6	28.1	34,760	57,500	19,310,000	40,390,000
	3	47.4	24.4	34,980	58,370	21,860,000	. . . . .
	4	45.9	26.5	34,980	58,060	18,900,000	42,910,000
	5	47.2	25.6	35,630	58,270	19,200,000	38,160,000
	6	40.1	25.0	35,050	57,850	18,940,000	43,000,000
	Av.	45.1	26.0	35,063	58,057	19,393,000	40,520,000
Transverse.	7	44.6	24.4	34,650	58,270	18,480,000	44,150,000
	8	44.4	24.4	33,550	58,730	26,840,000	41,560,000
	9	46.1	23.8	33,550	58,490	26,840,000	39,250,000
	10	44.5	22.5	34,520	59,470	15,010,000	64,800,000
	11	45.2	23.8	35,680	58,170	23,780,000	45,440,000
	12	46.4	25.0	34,650	58,390	27,730,000	50,460,000
	Av.	45.2	24.0	34,433	58,587	23,113,000	45,943,000

Chemical Analysis, C = 0.18%, S = 0.04%,
P = 0.032%, Mn = 0.45%.

TABLE II.—NO. 1 MARINE STEEL.

	No.	Contraction, Per Cent.	Elongation, Per Cent.	Stress at Elastic Limit.	Ultimate Stress.	Modulus of Elasticity.	
						At Elastic Limit.	At One-half Elastic Limit.
Longitudinal.	13	62.0	31.9	25,810	47,690	17,200,000	42,730,000
	14	64.3	35.0	25,820	47,230	16,660,000	52,425,000
	15	62.1	32.5	26,330	47,690	30,080,000	55,440,000
	16	62.8	33.8	25,920	47,130	19,200,000	39,320,000
	17	66.5	33.1	24,880	46,890	21,635,000	50,040,000
	18	64.8	32.5	26,310	47,020	20,240,000	45,770,000
	Av.	63.7	33.1	25,845	47,275	20,836,000	47,621,000
Transverse.	19	58.5	33.7	25,850	47,600	23,500,000	42,060,000
	20	62.7	33.8	25,920	47,000	23,560,000	39,500,000
	21	67.0	33.1	25,570	46,970	26,225,000	45,260,000
	22	60.0	32.5	26,590	46,820	18,330,000	45,450,000
	23	60.1	33.1	26,910	47,320	15,380,000	46,410,000
	24	59.9	33.1	26,730	47,120	22,270,000	50,800,000
	Av.	61.4	33.2	26,260	47,140	21,544,000	44,827,000

Chemical Analysis, C = 0.13%, S = 0.026%,
P = 0.004%, Mn = 0.45%.

As shown in Fig. 2, the extensometer is of the lever type and records the extension directly on a revolving drum multiplying the elongation in the ratio of 50 to 1. The object in designing this instrument was to make an extensometer which should be attached directly to the specimen and should be self-contained, not touching the testing machine itself and consequently not being affected by springing of the machine or by slipping of the jaws. It was desired that the instrument should contain the least possible number of moving parts and should be free from the errors due to the use of cords or belts.

Referring to Fig. 2, F and G are the upper and lower grips respectively, which are attached to the specimen, T, by pointed steel thumb-screws and connected together by a piece of light brass tubing. The lower grip, G, is pivoted to a collar which can be adjusted vertically on the brass tube by means of milled check-nuts. To G is attached the light steel lever L, carrying at its outer end the pencil or pen, P.

The lever is so proportioned that RP is 30 inches and the distance from the fulcrum, R, to the pointed screw is 0.6 inches, giving a multiplication of 50 to 1. The screw S enables the operator to adjust the pressure of the pencil on the paper, while the milled nuts and sliding collar on the lower grip provide for a vertical adjustment of the pencil.

By means of a bronze elbow the horizontal brass tube H, carrying the drum D, is attached to the extensometer in such a manner that the drum may be swung horizontally into the most convenient position for recording. The drum is rotated by a small worm, W, which in turn is connected by means of a very light double Hooke's joint to a shaft on the testing machine. This latter shaft is geared directly to the hand wheel which moves the poise on the beam of the machine. The drum is thus rotated an amount proportional to the load on the specimen, while the pencil moves up on the attached paper an amount proportional to the elongation of the specimen.

It will be seen that this instrument has no connection with the testing machine itself, except through the medium of the jointed shaft which drives the drum. This shaft is made of light tubing and is telescopic, so that there can be no pull or push exerted on the drum, and as the latter turns very easily there can be no appreciable deflection of the apparatus from this cause.

This particular instrument was designed for attachment to a

Riehlé machine, but it can be easily applied to any vertical testing machine. It may be thought that the instrument is rather heavy to suspend directly to the specimen, but no difficulty has been found in this respect. The present instrument, an experimental one, weighs but 5 lbs., and exerts a horizontal pull of only 8 lbs. on the screws of the upper grip.

If it were thought desirable, by employing aluminum and steel the weight could probably be reduced to three pounds, but the writer has found a certain mass to be of advantage to ensure freedom from vibration.

In Figs. 3 and 4 are shown sample autographs taken by this extensometer, one autograph from each set, as figured in Tables 1 to 4.

TABLE III.—NO. 2 FLANGE STEEL.

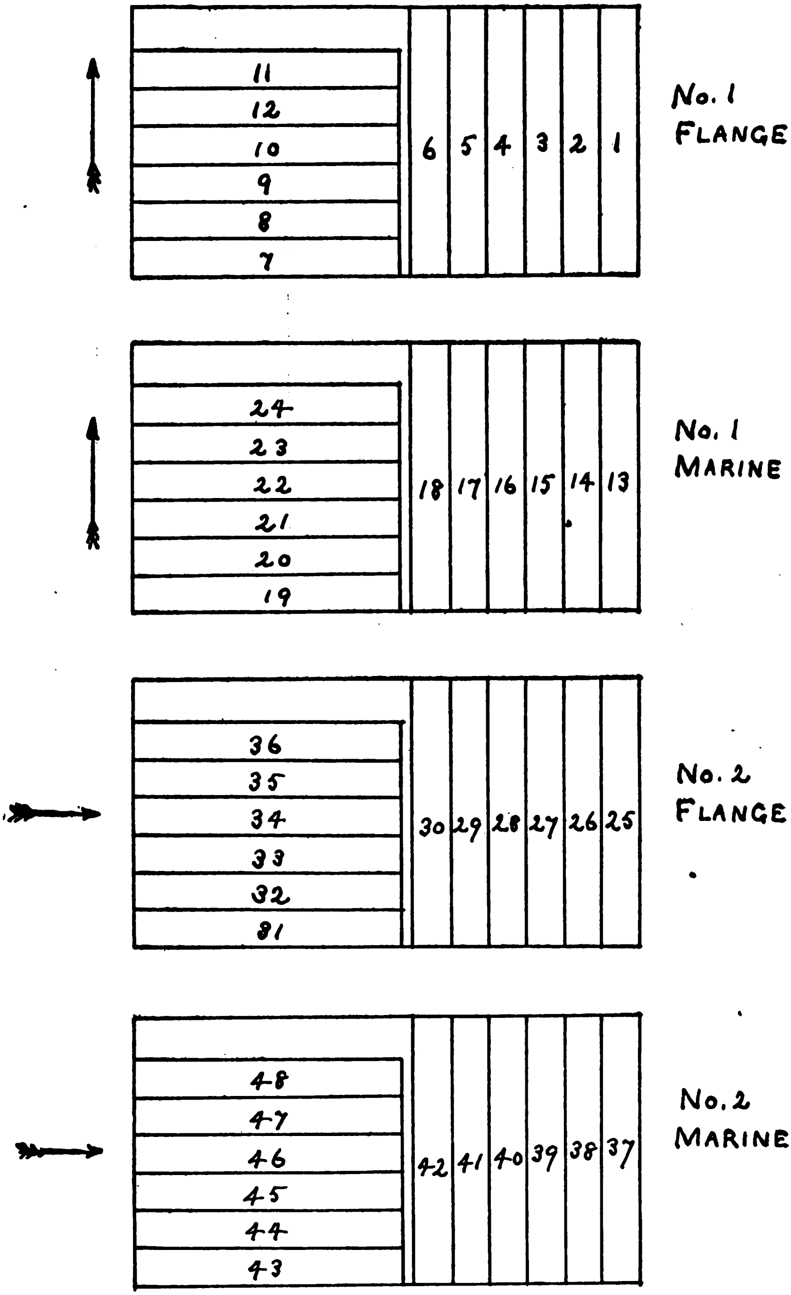
	No.	Contraction, Per Cent.	Elongation, Per Cent.	Stress at Elastic Limit.	Ultimate Stress.	Modulus of Elasticity.	
						At Elastic Limit.	At One-half Elastic Limit.
Transverse.	25	52.7	28.1	33,780	55,340	14,080,000	35,560,000
	26	50.4	26.9	33,340	55,340	14,490,000	44,440,000
	27	51.3	28.1	32,480	55,960	20,305,000	36,460,000
	28	50.7	27.5	31,340	55.110	17,910,000	40,140,000
	29	53.6	27.5	31,640	55,275	25,320 000	35,530,000
	30	50.0	28.1	30,360	55,460	18.400,000	42,020,000
	Av.	51.5	27.7	32,157	55,414	18,417,500	39 025,000
Longitudinal.	31	48.3	25.0	30 550	54,675	24,460,000	32,580,000
	32	39.1	12.5	32,960	57,250	11,990,000	42,040,000
	33	55.9	28.8	32,590	56,075	25.080,000	35.975,000
	34	54.5	25.6	32,920	56,200	26,340,000	54,200,000
	35	49.5	25.6	33,130	55.700	14.400,000	38,960,000
	36	52.8	25.6	33,610	55.600	24,560,000	40,720,000
	Av.	50.0	23.4	32,627	55,917	21,138,000	40,746,000

Chemical Analysis, C = 0.19%, S = 0.052%,
P = 0.04%, Mn = 0.45%.

Table IV.—No. 2 Marine Steel.

	No.	Contraction, Per Cent.	Elongation, Per Cent.	Stress at Elastic Limit.	Ultimate Stress.	Modulus of Elasticity.	
						At Elastic Limit.	At One-half Elastic Limit.
Transverse.	37	51.3	25.0	34,350	58,290	19,630,000	39,960,000
	38	53.6	24.4	34,290	57,900	28,580,000	59,740,000
	39	53.1	27.5	32,790	56,150	22,610,000	36,430,000
	40	57.0	25.0	31,170	55,360	15,990,000	50,640,000
	41	52.3	26.9	32,760	55,590	24,270,000	47,230,000
	42	53.0	28.8	31,810	55,710	21,210,000	35,020,000
	Av.	53.4	26.3	32,862	56,500	22,048,000	44,837,000
Longitudinal.	43	63.0	. . . .	33,080	51,910	25,450,000	40,140,000
	44	65.6	. . . .	34,630	51,150	26,640,000	52,430,000
	45	61.0	. . . .	34,800	51,290	25,780,000	41,250,000
	46	63.4	. . . .	32,830	51,710	26,270,000	40,680,000
	47	63.5	. . . .	33,140	51,150	25,500,000	38,900,000
	48	60.6	. . . .	33,180	53,290	27,590,000	37,560,000
	Av.	63.0	. . . .	33,610	51,750	26,205,000	41,827,000

Chemical Analysis, C = 0.13%, S = 0.031%,
P = 0.028%, Mn = 0.46%.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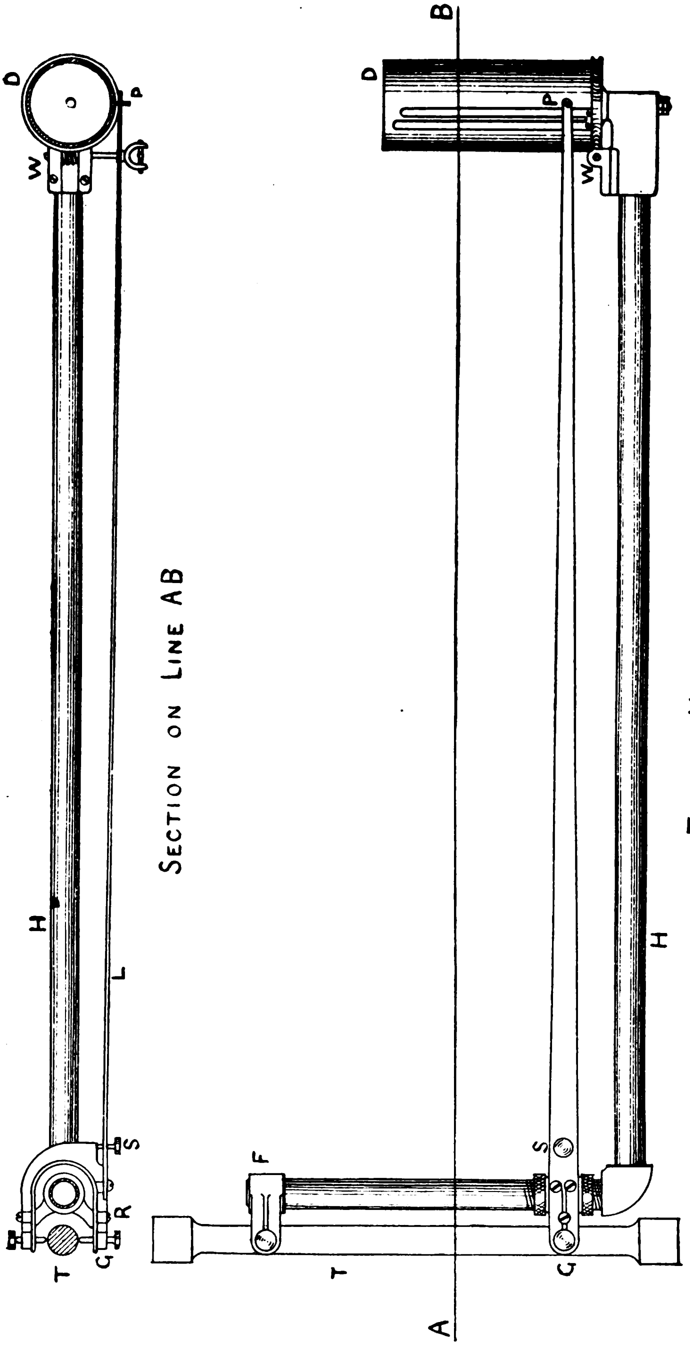
FLANGE
No. 1
MARINE
No. 2
FLANGE
No. 2
MARINE

FIGURE I.



Section on Line AB

Front View.

Figure II.

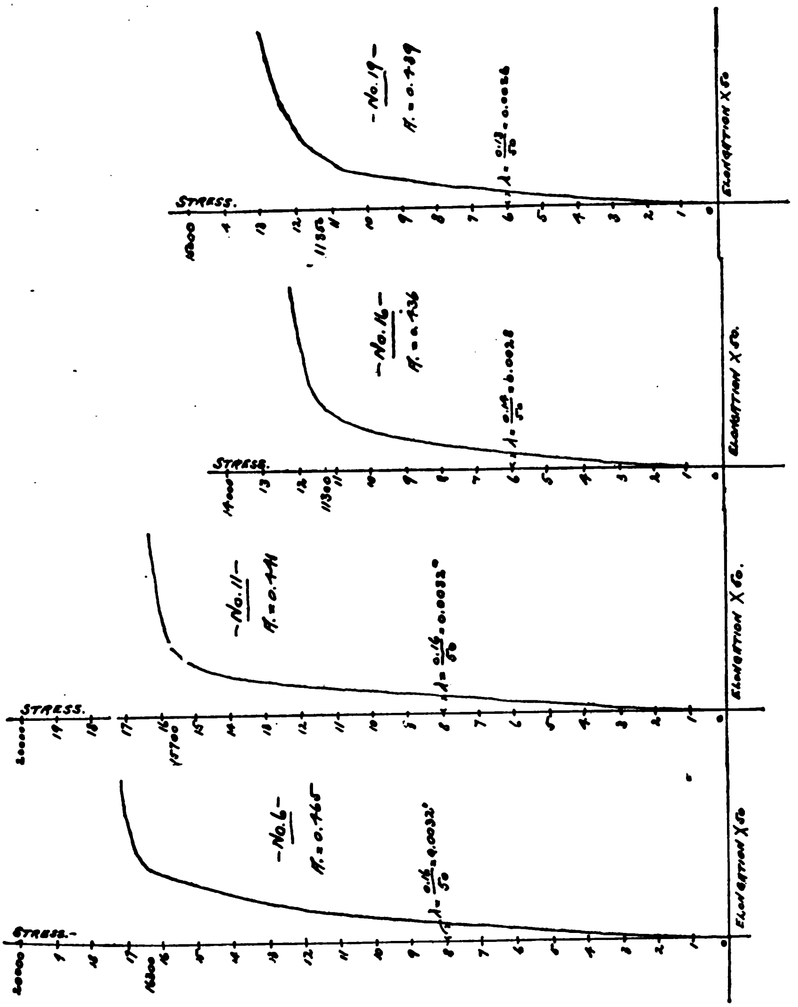

STRESS.
– No. 19 –
A. = 0.789
$\lambda = \frac{0.13}{50} = 0.0026$
ELONGATION X 50
STRESS.
– No. 16 –
A. = 0.736
$\lambda = \frac{0.14}{50} = 0.0028$
ELONGATION X 50
STRESS.
– No. 11 –
A. = 0.791
$\lambda = \frac{0.16}{50} = 0.0032$
ELONGATION X 50.
STRESS.
– No. 6 –
A. = 0.765
$\lambda = \frac{0.16}{50} = 0.0032$
ELONGATION X 50
20000
15700
11300
11350

FIGURE III.

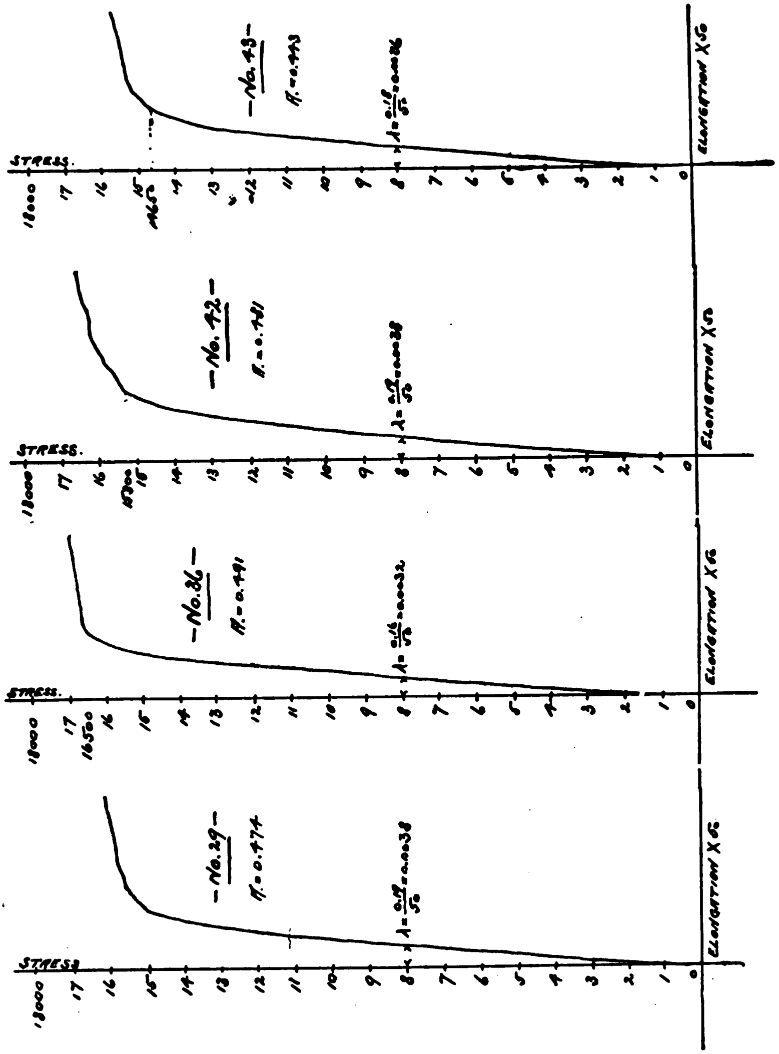

STRESS.
18000
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
ELONGATION X 50
— No. 43 —
A. = 0.443
λ = 0.18/50 = 0.0036
14650
— No. 42 —
A. = 0.481
λ = 0.19/50 = 0.0038
15300
— No. 36 —
A. = 0.491
λ = 0.16/50 = 0.0032
16500
— No. 29 —
A. = 0.474
λ = 0.19/50 = 0.0038

FIGURE IV.

TESTING.

IT is questionable if any department of mechanical science has made such rapid strides for the determination of reliable data as testing. If we look at the matter in a common-sense way, nothing else but gradual improvement can be expected. Among mechanicians who are constantly engaged in new developments, an every-day-expression is "wonder how it will stand?" The answer comes, "try it, test it." To accomplish all the requirements of testing means an immense amount of study; a thorough knowledge of machine design of the most accurate form, and an up-to-date experience in the material used for testing. In Britain and Europe testing has long been an established necessity for almost every commercial article upon which any reliance is demanded. We here are pushing forward, in every branch of this most interesting science, to obtain best results in manufacture, to possess reliable data, and to check the manufacturer who would—were it not for testing—send out an inferior and faulty article.

Our esteemed contemporary, *The American Machinist*, in its issue of November 26th, seems rather inclined to throw a shadow over this all-important subject, suggesting that "horse-sense and a knowledge of dark ways, etc., are needed to detect the efforts of interested parties to deceive the expert in charge."

Expert is a term used to define one thoroughly versed in a subject upon which he is engaged. Unfortunately, in many instances, the man in charge is not equal to the term, hence it proves inexperience in this direction is alone responsible for bad and "watered" tests. But this fact does not show that the science is at fault.

Further on *The Machinist* proclaims that the "real brain-racking problems are solved over the drawing-board and in the shop."

I have often heard it said, and seen verified in practice, that "money is made and lost in the drawing-room." It would appear to any engineer of common sense that the less his assistants knew about the physical properties of the material used in construction, the greater would be the errors and consequently his losses. To us it seems absolutely impossible for any student or engineer in practice to devote himself to construction without a very large and correct knowledge of the physical properties of material upon which he is engaged—whether he got this from text-books or otherwise, it is purely the outcome of the result of testing. It is possible that there are investigations made in schools totally unnecessary for practice and perhaps have absorbed much time and expense in their preparation, yet it is and must be interesting to the student, for he gleans much from the contact with the operation, in being able to investigate the delicate machinery and its mode of construction. In these elaborations it is not testing, nor is it the student, to blame, but the professor who, perhaps due to his advanced ideas, has a failing toward measuring the infinite. *The Machinist* would have us believe that the only subject studied in our engineering schools is machine design. Civil, electrical, and mining engineers all are intensely interested in the development of the physical properties of materials through the medium of testing.

Our contemporary says: "Machine building is primarily a matter of business and not of science, and this worship of tests and efficiency tends directly to obscure this fact and to lead to the reverse conclusion."

Experience alone is the "matter of business," which is only the outcome of endless contact with the possibles and impossibles, investigating previous experience, experimenting on that which has been done; in short, it comes down to a most potent yet simple fact: trial or test; it is undeniably the practice, and is the only means of proving or disproving theory. The more we test and measure the efficiency of a machine the better able are we to determine the quality of material; the best mode of improving its defects, whether this or that oil is best suited for its lubrication, etc. A testing laboratory is of the utmost importance, because it often saves much labor in predetermining a quantity otherwise unsolvable, thus giving the constructor confidence in his work, relieving him of the uncertainty and worry of waiting the result of failure or success in any detail of his work after its construction. Again our contemporary complains of the elaborate machinery in our schools. If a little time was given in figuring out the number of students attending the mechanical engineering courses, and allow that each one should himself participate in the preparation and carrying out of a test, it will be found that nine cases out of ten the experimental machinery is miserably inadequate, making it impossible for the individual student to test alone, or even in company with another. Generally our colleges that have good incomes, and whose patrons believe in bringing students in close touch with the times, provide experimental machinery in proportion to the demands made upon it. Other poorer institutions struggle along without such necessities, but always in a complaining tone, deploring their condition. But it is not the schools that have all the testing appliances. Nearly every engineering concern of repute has a testing room of some sort, many extremely elaborate. May we ask, is it because they have money to throw away? No; they appreciate the fact of being able to determine themselves the means whereby they can improve their output, or their machines, as the case may be, and fill the conditions of a binding contract. Thus we see the schools are endeavoring to follow only in the wake of actual practice, guided by their able instructors, the majority of whom are men in close harmony with things that are and can be, who feel the importance of machinery for experiment as object lessons, to hasten the students' education in so wide a field. Many of our old instructors envy the path of students nowadays, because of the easy access to the means of solving problems they had to struggle years to determine. As time advances greater knowledge is developed, greater demands are made upon man, and he alone can succeed who is cognizant of the present condition of the sciences. He alone can stand the test.

EDITOR.

STRENGTH OF WELDS.—Some experiments made at the engineering laboratory of the University of Michigan to determine the strength of welded joints are especially interesting. Of a number of the specimens tested not one broke in the weld; as some of these were slightly larger at the weld, a new set of specimens was prepared and a cut taken from each in the lathe to reduce the piece to a uniform diameter throughout its length between the jaws of the testing machine. Common round iron was used. Three bars were taken at random; 1¼ inches, 1 inch, and ¾ inch in diameter. From each bar four specimens were prepared, one solid, one lap-welded, one butt-welded, and one split-welded. The results show that only two specimens, both lap-welded, broke at or near the weld; the fracture in one case was slightly crystalline and in the other fibrous. The strength in no case departed widely from the strength of the solid parts. It would seem from these tests that with skillfully made welds we may expect to realize nearly the full strength of the original bar.

PHYSICAL TESTS OF MATERIALS.

By R. H. Thurston, Director, Sibley College, Cornell University, Ithaca, N. Y.

IT gives me great pleasure, in compliance with the request of the editor of THE DIGEST OF PHYSICAL TESTS, to submit a few suggestions relative to methods and purposes of some such work that may perhaps prove helpful to those seeking to find a special field of research in this department. The value of the matter already accumulated and so well presented in this journal is, perhaps, the best possible evidence that the skilled investigator in engineering can find no field in which his explorations are likely to be more fruitful of valuable and professionally helpful result. A few historical reminiscences may suitably introduce the subject-matter and preface our conclusions.

In the course of the year 1873 plans for the organization of a "Mechanical Laboratory," given shape in 1871 and earlier by the writer, began to take material form, and that year was marked by the entrance of their author upon a series of investigations relative to the various effects of method and time of stress and of strain upon the materials of construction, using for much of the work a form of "autographic recording testing machine," which was, so far as known, the first of that class. The first test-piece placed in the machine gave an "autographic" diagram on which was recorded a discovery which attracted very general attention, and proved the introductory to a very extended series of researches in his own laboratory and also abroad. It was the recorded fact of "the exaltation of the normal elastic limit-series by time and strain." This discovery was reported to the American Society of Civil Engineers in the autumn of that year.*

The effect of the "Flow of Metals," and of the force of polarity described by Prof. Henry, in modifying their resistance to external stress and their strain, was stated by the writer as follows: †

"The same molecular movement, or flow, which rearranges the internal force and relieves internal strain may be a phase of that viscosity which Vicat supposed might in time permit rupture of metal subjected to stress nearly approaching its original ultimate resistance, the one action being a more immediate result than the other, and the latter producing its effect, even when cohesive force may have been actually intensified.

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* *Trans. A. S. C. E.*, Vol. III, p. 13.

† *Ibid.;* also *vide Trans. A. S. C. E.*, March 1st, 1876.

"It was noted, however, that in the cases in which wrought iron and steel had been subjected to stress exceeding the elastic limit the metal had exhibited no tendency to flow, and that in nearly every case observed an actual 'elevation of the elastic limit by strain' had taken place. No experiment had then been made by the writer in which the same sample had exhibited both the elevation of the elastic limit by strain and the phenomenon of flow.

"Since that time, when experimenting upon copper, strain-diagrams produced automatically have been observed to exhibit this double effect. The elevation of the elastic limit has occurred in the earlier part of the test, and, at a later period, the strain-diagram exhibits flow, the metal yielding under a gradually decreasing stress. The progressive distortion which had never been observed by the writer in iron or steel, has since been frequently noted in other materials."

* * * * * * *

The paper referred to thus enunciated a principle which was deduced from experiments on wrought iron which is, if possible, of more vital importance to the engineer than the facts just given, viz.: That the time during which applied stress acts, is an important element in determining its effect, not only as an element which modifies the effect of the *vis viva* of the attacking mass and the action of the inertia of the piece attacked, but, also, as modifying seriously the condition of production and relief of internal strain by even simple stresses.*

It was also shown, by autographic strain-diagrams, that some materials yield the more readily the more rapidly the distortion and rupture are produced, their resistance varying in some inverse ratio, with the rapidity of change of form. It was further indicated that this action might be closely related to the opposite phenomenon of the elevation of the elastic limit by strain. An explanation was offered in the theory that, with rapid distortion insufficient time is allowed for the relief of internal strain in materials capable of exhibiting that condition. It was further remarked that "the most ductile substances may exhibit similar behavior, when fractured by shock or by any sudden applied force, to substances which are comparatively brittle," and illustrations were given of such behavior, and the precautions to be taken by the engineer, in view of this important modification of the resistance of materials by velocity of rupture, were stated.

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* Vol. III, page 30. LXI. Vol. II, page 239. CXV. Vol. IV, page 334.

"Should it be true, as suggested by the writer, that the cause of the decreased resistance, sometimes observed with increased velocity of distortion, is closely related to the cause of the elevation of the elastic limit by strain,* it would seem a simple corollary, that *materials so inelastic and so viscous as to be incapable of becoming internally strained during distortion should offer greater resistance to rapid than to slowly produced distortion,* in consequence of their inability to 'flow' so rapidly as to reduce resistance by such fluxion at the higher speed, or by correspondingly reducing the fractured section. This principle has been shown, by a large number of experiments, to be frequently, if not invariably, the fact. Copper, tin, and other inelastic and ductile metals and alloys are found to exhibit this behavior, and are, therefore, quite opposite in this respect to ordinary wrought iron and worked steel."

The writer had noted the fact that very soft wrought iron does not always exhibit an observable elevation of the elastic limit by strain, and Com. L. A. Beardslee, U. S. N., had observed that the softest and most ductile specimen of iron then tested by him at the Washington Navy Yard exhibited a perceptible increase of resistance with a considerable increase of rapidity of extension. This metal was peculiar in its softness and extreme extensibility. All the irons of commerce appear to belong to the other class, as then shown.

Autographic strain-diagrams, given by this class of metals, exhibited smooth, straight, and horizontal lines for long distances on the paper where the distortion is produced by a uniform motion. Increasing the rapidity of distortion caused an immediate and sustained elevation of the pencil, and a decrease of velocity causes the line to droop to a lower level. In some experiments a torsion of one revolution in a half-hour, the test-piece being ⅝-inch diameter and one inch long, just kept the pencil on a horizontal line.

Two test-pieces from the same bar were broken, the one rapidly, the other slowly. The former gave a strain-diagram of which

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* *Transactions,* Vol. III, page 363.

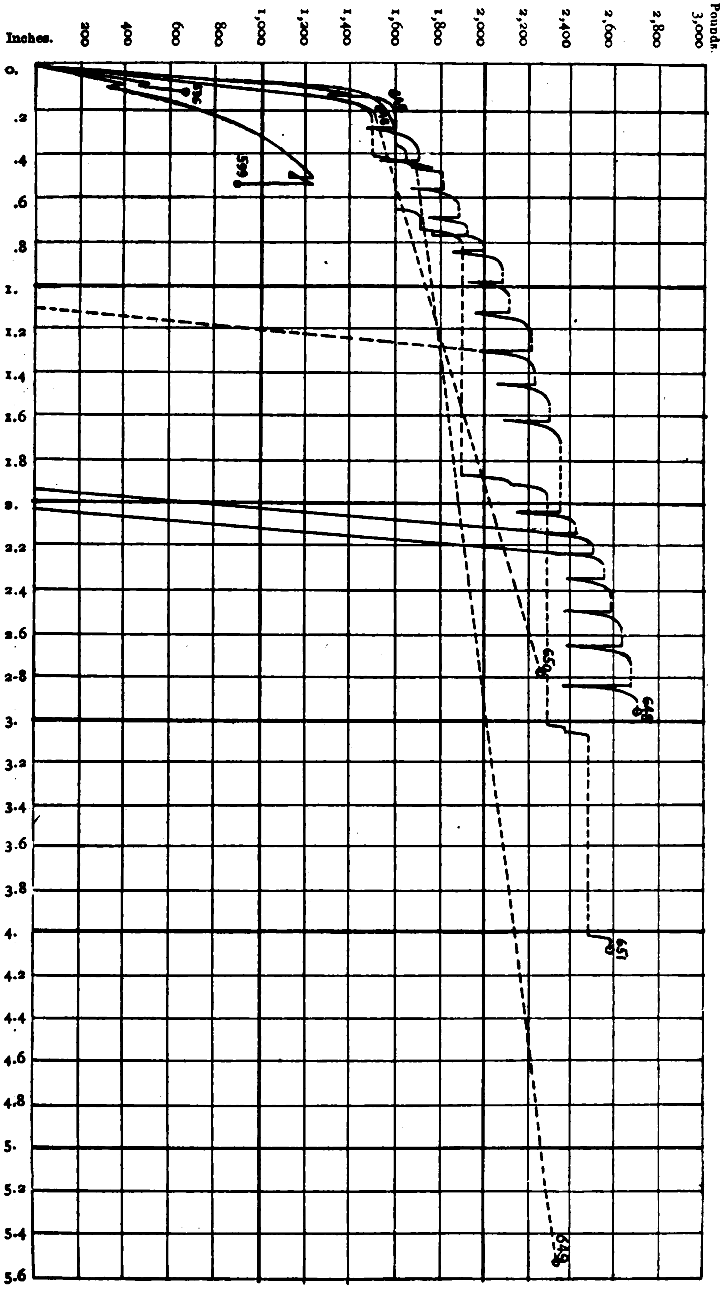

FIG. I.—STRAIN-DIAGRAMS OF FOUR BARS OF WROUGHT IRON, AND TWO OF COPPER-ZINC ALLOYS TESTED BY TRANSVERSE STRAINS. ROBERT H. THURSTON.

the maximum ordinate was about 50-foot pounds higher than the maximum of the latter, the difference being nearly 50 per cent. of the higher.

"It is evident that, whatever the character of the material and whatever the velocity of rupture, the effect of the *inertia* of the mass, and of particles not immediately affected by a shock, remains, and that its effect is *always* to reduce the resilience of the metal and its resistance to shock; and this reduction may, in many cases, more than compensate the increase of resistance here noted. Its tendency is always to produce a sharp fracture which, with such sudden blows as are given by cannon shot, for example, may resemble the break characteristic of brittle and non-ductile substances."

The writer proposed, therefore, to divide the metals used in construction into two classes:

1st. Metals subject to internal strain by artificial manipulation and which may exhibit an elevation of the elastic limit by strains and decreased power of resisting stress under increasing rapidity of distortion. The ordinary irons of commerce are typical of this class.

2d. Metals of an inelastic viscous character, not subject to internal strain, and not usually exhibiting an elevation of the elastic limit by strain, and which offer increased resistance when the rapidity of distortion is increased. Tin is a typical example of this class.

It is obvious that the value of the former class for the construction of the engineer is vastly greater than the latter, and especially for permanent loads and low factors of safety.

A study was later made of "the rate of set of metals subjected to strain for considerable periods of time," and this was the subject of a report to the A. S. C. E., in which were discussed the two distinct phenomena: the "decrease of resistance at a fixed distortion" and "the observed increase of deflection under static load." *

It was found that, with a fixed and invariable deflection, for example, of a bar of any one of the considerable variety of metals tested, including iron and the brasses and bronzes, the effort of the flexed bar to regain its initial form became less and less as time progressed, often approximating zero, and, at last, in the case of the brittle metals, fracture might even occur at loads, as in one case, at least, 25 per cent. lower than those the same bars had earlier sustained, and at still unchanged flexures.* The deductions were:

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* *Trans. A. S. C. E.*, December 6th, 1876.

"That in metals of all classes, under light loads, this decrease of effort and rate of set become less and less noticeable until, after some time, no further change can be observed, and the set is permanent."

"That in metals of the 'tin-class,' or those which had been found to exhibit a depression of the elastic limit with strain, a heavy load—*i. e.*, a load considerably exceeding the proof-strain, the loss of effort continued until, before the set had become complete, the test-piece yielded entirely."

"And that in the metals of the 'iron-class,' or those exhibiting an elevation of elastic limits by strain, the set became a maximum and permanent and the test-pieces remained unbroken, no matter how near the maximum load the strain may have been."

On the other hand, loading the bar with a given weight and allowing it free suspension, so that the deflection might take care of itself, it was found that the irons and steels, and usually and rarely an alloy, would deflect continually, more and more, to a limit; the deflection then ceasing, the bar would remain, indefinitely, unchanged. On the other hand, nearly all metals and alloys would exhibit a continuous and unintermitted depression, if the freely suspended loads approached their ultimate resistances, and even, in some cases, if it were above one-half the maximum momentary load which the metal was capable of carrying, and fracture would in time result; the time being the greater as the load was the smaller, proportionally. For most metals and alloys, and even for the woods, it was thus finally concluded, "an apparent factor of safety of two is actually but a factor of one." The real factor of safety, for permanent loading, is in such cases but about one half that which appears from a simple ordinary testing machine determination. For iron and steel, this is less true, if not entirely the reverse.

Based upon this fact of the "exaltation of the normal elastic limit by strain," the writer proposed "a new method of detecting overstrain in iron and other metals, and its application in the investigation of accidents to bridges and other constructions." † It was shown that the phenomenon above described, as then discovered and announced by the writer, produced a permanent record in the material itself, of the maximum stress to which it had been subjected; the elastic limit of a bar of iron or of steel which had been thus strained being the approximate measure of the stress thus applied. In fact, the elastic limit may arise somewhat after the stress has been removed.

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* *Ibid.*, Section 1. Such fracture did not occur with iron.

† *Trans. A. S. C. E.*, March 20th, 1878.

For good bridge irons, the amount of the excess of the exalted limit, as shown by subsequent test, above the stress at which the load had been previously removed was expressed approximately by the formula:

$$E^1 = 5 \text{ Log. } T + 1.50 \text{ per cent.};$$

in which the time, T, is given in hours of rest after removal of the tensile stress which produced the noted stretch.

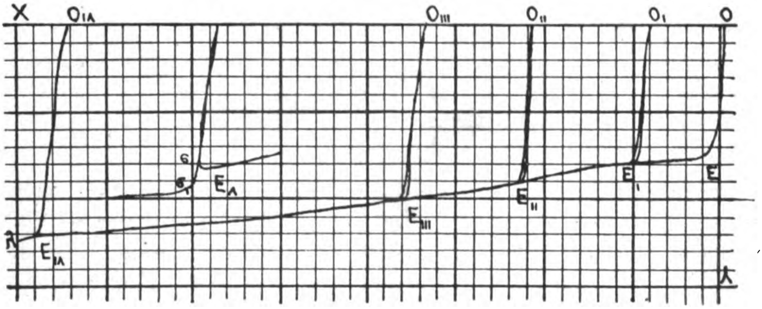

FIG. 2.—EXALTATION OF ELASTIC LIMITS.

"Thus, in the figure, which is a *fac simile* of a part of a strain-diagram produced by such an iron, during a test in which the intermission of stress was of too brief duration to cause an observable exaltation of the normal elastic limit in a diagram drawn on so small a scale, the point E is the primitive elastic limit of the material, and $E^{\rm I}$ $E^{\rm II}$ E $E^{\rm IV}$, are the normal elastic limits corresponding to sets under loads which have strained it beyond that primitive elastic limit. In the example here illustrated the primitive limit is found at about 20,000 pounds per square inch, or 1,400 kilograms per square centimeter, and the other points are those corresponding to loads of, respectively, 21,000, 22,500, 25,000, and 30,000 pounds on the inch, or to 1,470, 1,575, 1,750, and 2,100 kilograms on the square centimeter. The corresponding extensions, as shown on the diagram, are 1.25, 2.53, 4.50, and 6.78 per cent.

Had the stress been intermitted at either of these points any considerable period of time, there would have been observed a rise in the diagram as above stated like that shown in Fig. 1, at E^{v} the normal elastic limit *e*, being, on subsequent test, found altered and a new limit, *e′*, observed. The extent of this elevation of the limit would be the greater as the time of rest was greater, as was then shown.

Thus it was proved that a metal, once overstrained, carries, permanently, unmistakable evidence of the fact,* and can be made to reveal the amount of such overstrain at any later time with a fair degree of accuracy. This evidence cannot be entirely destroyed, even by a moderate degree of annealing. Often only annealing from a high heat, or reheating and reworking, can remove it absolutely. Thus, too, a structure broken down by causes producing overstrain in its tension members, or in its transversely loaded beams (and, probably, in compression members, although the writer is not yet fully assured of the latter), retains in every piece a register of the maximum load to which that piece has ever been subjected; and the strain-sheet of the structure, as strained at the instant of breaking down, can be thus laid down with a fair degree of certainty.

Here, then, when the work thus performed shall have been properly complemented with experimental determinations of the behavior of all the materials of general use in construction, is to be found a means of tracing the overstrains which have resulted in the destruction or the injury of any iron or steel structure, and of ascertaining the cause and the method of its failure, in cases frequently happening in which they are indeterminable by any of the usual methods of investigation.

The fact of the normal variation of the elastic limit, as change of form progresses under gradually increased load, was fully established by the experiments of Hodgkinson, Clark, Mallett, and other English investigators; by Tresca, particularly, in France; by Werder and Bauschinger in Germany, and by Beardslee, the writer, and others in the United States.

The exaltation of the series of normal limits so produced, still further, as shown by the writer and as seen in Fig. 1, by the intermission of strain, as at E^{v}, is now a matter of no uncertainty as to its character, although still more study is needed to determine the modifying effects of time of intermission of stress with the two great classes and when not of the same composition. The method then outlined of determining the extent of previous overstrain may, therefore, be expected to have many useful applications.*

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* The writer has found by subsequent tests that every strain produces the same effect upon the elastic limit for all directions of stress.

It was shown in this paper that it is, in some cases, at least, perfectly possible to trace the varying stresses which have occurred in the members of a bridge, broken down by any accident, in such manner as to discover the point at which the maximum load was applied in its fracture, and thus to, in some cases, ascertain the probable cause and method of breakdown. A typical example, closely corresponding to an actual case investigated by the writer, was illustrated.

It was found, as then shown, that the load on the structure at the time of the accident was but sufficient to make the maximum stress on these rods—if properly distributed—20,000 pounds per square inch at the threaded part of the piece; which piece, it had been seen, had been broken by a strain nearly double that figure. The fact was at once inferable that the load came upon these members with such suddenness as to have fully the effect of a live load (as taken in the text-books) and giving a maximum stress equal to twice that produced by the same load gradually applied—*i. e.*, the case in which the load falls through a height equal to the extension of the piece strained by it, the resistance being assumed to increase directly as the extension up to the point of rupture—an assumption which is approximately correct for brittle materials like hard cast iron, but quite erroneous in the case of some ductile materials, which latter sometimes give a work of ultimate resistance amounting to three-fourths or even five-sixths of the product of maximum resistance by the extension.

This accident was thus really caused by the entrance upon the bridge of a load capable of straining the metal to about one-half of its ultimate strength, if slowly applied, but which, in consequence of its sudden application, doubled that stress.

"This sudden action may have been a consequence either of its coming upon the structure at a very high speed, or a result of the loosening of a nut, or of the breaking of a part of either the bridge floor or of one of the trucks of the train. The latter occurrence, permitting the load to fall even a very small distance, would be sufficient."

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* *Trans. A. S. C. E.*, Vol. VII, 1878.

TENSILE STRENGTH OF WROUGHT-IRON BARS, ORIGINAL STRENGTH AND STRENGTH AFTER THE BARS HAD RESTED; ALSO STRENGTH AFTER ANNEALING.—*U. S. Report*, 1882.

No. of Test.	Condition of bar when tested.	Size of bar when tested.			Strains on original section.		Strains on reduced section.		Uniform elongation from original length.	Contraction of area from original section.	Appearance of Fracture.	Remarks.
		Width.	Thick.	Sectional area.	Elastic limit.	Ultimate strength.	Elastic limit.	Ultimate strength.				
		In.	In.	Sq. inch.	Lbs. per sq. in.	Lbs. per sq. in.	Lbs. per sq. in.	Lbs. per sq. in.	Per cent.	Per cent.		
993	Original, ...	3.05	1.00	3.05	29,500	51,150	. . . .	. . . . .	21	31 5	Fine fibrous.	
	Rested four months since original test,	. . .	. . .	. . .	. . . .	60,000	. . . .	. . . . .	24	. . .	Fibrous, 90 per ct.; granular, 10 per ct.	
994	Original, ...	3.05	1.00	3 05	28,500	51,110	. . . .	. . . . .	21	36.1	Fine fibrous	
	Rested four and two-third months, . .	. . .	. . .	. . .	53,440	61,960	. . . .	. . . . .	25	33.8	Fibrous, 92 per ct.; granular, 8 per ct.	
981	Original, ...	3.05	1 01	3.08	28,000	50,390	. . . .	. . . . .	14	35 1	Fibrous.	
	Rested five months,	. . .	. . .	. . .	. . . .	60,390	. . . .	. . . . .	20	21.8	Granular, 70 per ct ; fibrous, 30 per ct.	
973	Original, ...	5.05	1.28	6.46	27,500	50,500	. . . .	. . . . .	13	24.2	Fibrous, 95 per ct.; granular, 5 per ct.	
	Rested eight months,	. . .	. . .	. . .	56,500	58,980	. . . .	. . . . .	18	17.	Fibrous, 30 per ct.; granular, 70 per ct.	
	Heated cherry red and cooled in open air, ...	4.75	1.17	5.56	21,670	36,220 41,640	26,080	42,090 48,380	33	. . .	Fibrous, ...	Broke at end of annealed section.
774	Original, ...	3 03	1.01	3 06	29,500	53,630	. . . .	. . . . .	16	36.	Fibrous, 92 per ct.; granular, 8 per ct.	
384	Rested ten months, .	2.84	0.94	2.67	53,920	63,130	61,800	72,360	23	21.9	Granular.	
385	Heated dull red and cooled in open air,	2.80	0.92	2.58	22,800	41,240	27,130	48,910	32	34.0	Dull fibrous.	
777	Original, ...	3.03	1.01	3 06	29,000	53,560	. . . .	. . . . .	15.	37.9	Fibrous.	
386	Rested ten months, .	2.87	0 95	2.73	53,920	63,070	60,440	70,696	19	19.6	Fibrous, 10 per ct.; granular, 90 per ct.	
387	Heated to 370 degrees and cooled in open air, . . .	2.83	0.92	. . .	57,520	57,520	67,700	67,700	19	34.6	Fibrous, 60 per ct.; granular, 40 per ct.	
	Rested fifteen days after third test, . .	. . .	. . .	. .	. . . .	62,420	. . . .	. . . . .	. . .	. . .	Fibrous, 60 per ct.; granular, 40 per ct.	
971	Original, ...	3.03	1.01	3.06	32,500	53,500	. . . .	. . . . .	16	27.5	Fibrous.	
388	Rested nine months,	2.84	0.94	2.67	55,880	63 360	64,040	72,620	21	19 9	Fibrous, 30 per ct.; granular, 70 per ct.	
389	Rested nine months,	2.84	0.92	2.61	. . . .	66,010	. . . .	77,400	21	19 9	Fine granular.	

"The same method may sometimes be used to ascertain the probable cause of a boiler explosion by determining whether the metal has been subjected to overstrain in consequence of overpressure. The causes of accidents to machinery may also be thus detected, and many other applications will suggest themselves to every engineer."

Subsequently to the publication of these facts and deductions, experiment showed that strain of the metal in any direction affected the elastic limit measured in any other direction of stress.*

A test-piece, strained in tension, showed exalted elastic limits in compression, torsion, and transverse tests, and a primitive strain in either of the latter directions affected all the elastic limits in the other directions. The permanent effects of strains in metals and their self-registration, like the other phenomena of this class already alluded to, as well as their known mutual interactions, constitute an exceedingly important field of further study and research on the part of the metallurgist and the engineer. It is to this field of study that the writer would invite the attention of such investigators. The exploration of this field has but just begun. In conclusion is introduced the tabulated results of an interesting series of similar determinations made subsequently (1882) at the Watertown Arsenal, upon the great Emery testing machine, purchased by the "U. S. Board appointed to test Iron, Steel, and other Metals," and inherited by the Ordnance Bureau of the War Department.† An extremely valuable and interesting collection of data bearing upon this department of research may be found in the report of that commission, and it may well be questioned whether any more probably fruitful and useful lines of investigation could be found than those which are related to the facts above referred to. They are of real and practical value to the engineer.

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* *Trans. A. S. C. E.*, Vol. XXIV, 1891.

† *Report of U. S. Board*, 2 vols., 8vo; R. H. Thurston, Editor; Washington, Gov't Printing Office, 1878.

ALLOYS OF IRON AND NICKEL.*

By Professor M. Rudeloff.

A SPECIAL committee having been appointed to study the properties of iron alloys, Prof. M. Rudeloff, Assistant Director of the Royal Prussian Testing Department, reported recently to the *Verein zur Beförderung des Gewerbfleisses* on alloys of iron and nickel. Thirteen different mixtures were produced, three ingots from each mixture. The ingots weighed 20 kg. each and measured 15 inches in length, 2½ inches thick and 4 inches wide. Their chemical composition is given in Table I.

CHEMICAL COMPOSITION OF THE IRON USED.

	Iron.	Carbon.	Mang.	Silicon.	Phos.	Sul.	Copper.	Nickel and cobalt.
Per cent., . .	99.710	0.070	0.079	0.013	0.007	0.013	0.068	0.039

CHEMICAL COMPOSITION OF THE NICKEL USED.

	Nickel.	Iron.	Cobalt.	Copper.	Silicic acid.	Carbon.	Sulphur.	Alkalies Lime and alumina.
Per cent., ...	98.21	0.25	1.19	0.07	0.24	Trace.	Trace.	Trace.

PERCENTAGE OF NICKEL AIMED AT IN EACH GROUP OF THREE INGOTS—INGOTS NOS. 1–3 WERE PURE IRON; NOS. 37–39 PURE NICKEL.

Ingot No.	1–3	4–6	7–9	10–12	13–15	16–18	19–21
Per cent. of Nickel, . .	0.00	0.50	1	2	3	4	5
Ingot No.	22–24	25–29	28–30	31–33	34–36	37–39	
Per cent. of Nickel, . .	8	16	30	60	95	100	

The method of melting the material was uniform in all cases. The fuel used was coke and the melting was done in graphite crucibles. Before pouring, a small amount of aluminum, or magnesium, or ferromanganese was added to make the metal more fluid. At first the inside of the mold was washed with chalk. This proving objectionable, causing checks and rough surface of the ingots, a clay wash was substituted with better results.

The pure iron, and mixtures rich in iron, required the addition of 20 gm. of aluminum to 20 kg. of metal to produce the required fluidity for casting. On the other hand, 10 gm. of magnesium prevented spongy ingots with the nickel, or mixtures rich in nickel. For the purpose of chemical analysis the ingots were sawed in two and the surface planed. The chips thus obtained were then used for chemical analyses. The strength of the alloys produced was ascertained by tensile and shearing tests, by slow compression and crushing under the drop. Three test-pieces from each ingot for each kind of test were prepared. The degree of expansion by heat was determined on four ingots, one of pure iron and pure nickel each, and one with 4 and 16 per cent. nickel, respectively. By the tensile test the elastic limit, yield point, breaking strength, and elongation were determined. Average results of tests are given in Table II. In Table III the proportional strength of alloy to pure iron is given, the iron being taken as 100. In the compression tests the yield point was determined and the percentage of reduction from the original height, under a load of 160,000 pounds per square inch. Results are found in Table IV.

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* **From the** *Verhandlungen des Vereins zur Beförderung des Gewerbfleisses.*

In the drop tests, 20 blows were given with a drop weighing 125 pounds, falling 9¼, 18½, 37 inches respectively. Results are given in Table V. Shearing tests were made by inserting the test-pieces in suitable holes of hardened steel washers, two of which were recessed in suitable blocks, one in each block, while a third washer sliding between the other two served as a shear by being forced down by means of a shear plate encircling the washer partly, and upon which pressure was exerted. Results are given in Table VI.

SUMMARY OF RESULTS OF TESTS.

Expansion by Heat.—The coefficient of expansion by heat was found to decrease with the increase of percentage of nickel, but was greater with the 98 per cent. nickel than with the pure iron. Taking the value of pure iron as 100, the difference in expansion was:

	Per Cent.
Iron and 4 per cent. nickel —	5.7
Iron and 16 per cent. nickel —	10.9
Iron and 98 per cent. nickel +	9.1

Or 94.3, 89.1, and 109.1 respectively.

Chemical Analyses.—A detailed examination of the analyses warrants the conclusion that the addition of nickel to iron does not appreciably influence the chemical contents of the iron in foreign elements. On the other hand, all foreign elements in the nickel are also found in the iron-nickel alloy.

TABLE I.

RESULTS OF CHEMICAL ANALYSIS OF INGOTS. AVERAGE OF THREE INGOTS.

Percentage of Nickel Aimed At.	Per Cent. of Iron.	Per Cent. of Nickel.
0.00	99.59	0.05
0.50	98.99	0.76
1.00	98.75	1.01
2.00	97.72	2.05
3.00	96.63	3.00
4.00	95.81	3 98
5.00	94.81	4.92
8.00	91.89	7 84
16.00	84.12	15.59
30.00	69.74	29.77
60.00	39.69	59.60
95.00	5.15	93.68
100.00	0.33	98.89

Tensile Tests.—The elastic limit, yield point, and breaking load rise until the percentage of nickel reaches about 10 per cent. Thence a decrease takes place of these values, until the nickel reaches 30 per cent. With a further increase of nickel the elastic limit and yield point decrease still more, while the breaking load is higher with 60 per cent. nickel than with 30 per cent., whence it decreases again.

The elongation decreases as the percentage of nickel increases, and is almost zero at 16 per cent. nickel. From there on elongation increases until with 60 per cent. nickel its maximum is reached, declining then with increase of nickel.

It will be seen that the elastic limit and yield point of pure nickel is only about 60 per cent. of the pure iron, the breaking load of the two metals are nearly the same, while the elongation of pure nickel is about 60 per cent. of that of the pure iron.

The elastic limit is raised highest by the addition of nickel, next the yield point, and then the breaking strength. The structure of the metal is likewise changed with changes in the percentage of nickel. In the pure iron the structure is amorphous. With 0.5 per cent. nickel the tensile fracture begins to get granular. With 5 and 8 per cent. nickel the structure is pronounced crystalline, the crystals assuming the shape of needles with 16 and 30 per cent. nickel, this structure continuing to the end of the series. With 0.5 per cent. nickel the ingots have a tendency to be honeycombed. They become sound with 1 per cent. nickel, continuing to be so up to 30 per cent. nickel, when the ingots exhibit oxidation in their interior.

TABLE II.

AVERAGE RESULTS OF TENSILE TESTS.

Per Cent of. Nickel.	Elastic Limit, Lbs. Per Sq. In.	Yield Point, Lbs. Per Sq. In.	Breaking Strength, Lbs. Per Sq. In.	Elongation, Per Cent. in 2 In.
0.05	8,535	20,768	46,100	29.7
0.76	8,819	22,617	45,652	20.6
1.00	10,242	23,613	47,938	26.4
2.05	14,500	28,734	52,632	22.7
3.00	22,900	34,144	57,753	20.1
3.64	23,630	28 265	57,750	17.6
4.93	27,881	46,230	63,443	10.8
7.84	32,433	62,874	79,944	9.6
15.60	22.760	. . .	58,322	0.6
29.78	8,962	17,781	14,225	2.2
59.66	8,535	17,780	53,770	36.1
93.55	5,832	15,363	47,221	19.0
98.56	5,121	12,944	43,386	17.1

TABLE III.

PROPORTIONAL STRENGTH OF ALLOY TO PURE IRON, TAKING IRON AS 100.

Per Cent. of Nickel.	Elastic Limit.	Yield Point.	Breaking Load.	Elongation in 1 Inch.
0.0	100	100	100	100
8	380	303	173	30
16	267	280	126	2
30	105	86	31	8
60	100	86	117	103
98	60	62	94	50

Compression Tests.—The resistance of the alloys to compression does not seem to differ in different parts of the ingot. The resistance increases steadily until 16 per cent. nickel is reached, whence it begins to decrease until at 94 per cent. nickel the resistance is only 50 per cent. of the pure iron. There is a small increase again with 98 per cent. nickel. Thus, generally speaking, the behavior of the alloys under compression is similar to their behavior under tension.

TABLE IV.

AVERAGE RESULTS OF COMPRESSION TESTS.

Per Cent. of Nickel.	Yield Point. Pounds Per Sq. In	Per Cent. of Reduction of Test-Piece Under a Head of 160,000 Pounds Per Square Inch.
0.05	25,900	47.8
0.56	22,500	47.4
1.01	28,300	45.5
2.06	37,200	42.1
3.01	40,700	38.8
3.98	40,100	37.5
4.92	54,900	34.1
7.84	72,500	29.2
15.60	163,700	0.7
29.78	30,300	37.5
59.60	22,900	33.1
93.52	13,900	34.6
98.89	18,000	36.9

Drop Tests.—The results of drop tests are more or less a repetition of the metal as exhibited in the compression tests. The strength increases up to 16 per cent. nickel, reaches the value of pure iron with 30 per cent. nickel, remaining in that condition to the highest percentage of nickel in the alloy.

TABLE V.

AVERAGE RESULTS OF DROP TESTS.

Per Cent. of Nickel.	Per Cent. Reduction of Test-Piece.		
	Distance of Weight Falling, 9¼ Ins.	Distance of Weight Falling, 18½ Ins.	Distance of Weight Falling, 37 Ins.
0.15	64.7	76.0	84.4
0.56	(63.3)	(76.7)	. . .
1.01	63.6	76.2	83.3
2.05	60.7	75.8	81.7
3.00	57.6	73.5	82.0
3.98	58.0	72.9	80.4
4.92	54.9	71.8	81.1
7.84	51.6	68.7	78.7
15.59	(25.3)	(46.7)	70.0
29.77	60.0	72.7	80.4
59.60	56.2	71.1	78.7
93.68	(58.0)	(71.9)	78.7
98.39	60.0	72.7	80.4

Figures in parentheses represent averages of less than three tests.

Shearing Tests.—The phenomena exhibited by the metal under shearing tests are very much like those observed at the yield point when the metal is under compression.

TABLE VI.

AVERAGE RESULTS OF SHEARING TESTS.

Diameter of Test-Pieces.		Diameter of Test-Pieces.	
Per Cent. of Nickel.	Load Applied to Shear in Lbs. Per Sq. In.	Per Cent. of Nickel.	Load Applied to Shear in Lbs. Per Sq. In.
0.05	37,800	7.84	61,870
0.56	36,800	15.60	96,300
1.01	40,400	29.78	50,200
2.06	43,400	59.60	53,900
3.01	47,400	93.52	50,800
3.98	49,100	98.39	49,400
4.92	52,000		

COMPARATIVE ANALYSIS

OF THE RESOLUTIONS OF THE CONVENTIONS OF MUNICH, DRESDEN, BERLIN, AND VIENNA, AND THE RECOMMENDATIONS OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, WITH THE CONCLUSIONS ADOPTED BY THE FRENCH COMMISSION IN REFERENCE TO THE TESTING OF METALS.

Report presented by M. L. Baclé, Member of the French Commission on Methods of Testing Construction Materials.

[Translations from the French and from the German by O. M. Carter, Captain Corps of Engineers, U. S. A., and E. A. Giesbler, U. S. Assistant Engineer.]

INTRODUCTION.

TWO attempts have been made abroad to secure the adoption of uniform methods of testing construction materials—one under the auspices of technical conventions held at different times in Munich, Dresden, Berlin, and Vienna, where, besides the German members, there were present delegates representing various foreign countries; the other, in America, under the auspices of the American

Society of Mechanical Engineers. Two reports presented to the Committee of Research, one by M. Polonceau and the other by M. Baclé, have given translations of the conclusions and recommendations thus adopted by the Conventions and by the American Society.

It is proper, therefore, to make a comparison between the resolutions adopted by foreign conventions and those adopted by our own commission, in order that we may examine the differences and analogies which they present. Such a comparison affords an opportunity of deciding whether there should be renewed study and research upon the points of difference, and of determining whether we may hope for international unity in the future, based upon the common resolutions already recommended and even now adopted in the current practical domestic relations of different countries.

The work of comparison in the present report, intended in some measure to form a starting point for the studies of an international commission which might be created for this purpose, has been confined to the methods of testing metals, which is the sole subject of discussion in Section A. (Section des Métaux.)

To facilitate comparison, avoiding as much as possible all omissions, an attempt has been made to place together all resolutions relating to the same subject, and to this end the methods of classification used in our General Report have been adopted. The present report follows, therefore, the divisions and rules of the General Report, giving under each chapter only such resolutions as offer a possibility of comparison with the corresponding foreign recommendations.

The comparison is usually made by referring to the resolutions of the Conventions, for those are frequently reproduced in the recommendations of the American Society. In certain cases, however, those two groups of resolutions present differences which then become the subject of special mention.

It is advisable to point out in a general way, among the resolutions to be compared, a primary difference in principle (which is, however, of little real importance) relating to tests made upon finished pieces. The resolutions of the Conventions, identical in this respect with the resolutions of the American Society, define the tests which should be made upon certain articles in current use, such as tires, axles, and rails. For certain kinds of metals, such as wrought or cast iron, for different specified uses, they advise the discarding of such tests as to them seem unnecessary, while our commission refuses to make any such elimination, feeling totally unauthorized to do so.

With regard especially to methods of testing, the studies of our Commission have been more general than those made abroad, and the recommendations that we have made include various kinds of tests not mentioned in the foreign resolutions, with which, therefore, no comparison is possible.

On the other hand, certain methods of testing have been especially recommended in all of the resolutions, such as tensile, shock, and bending tests, and it is with respect to those that the committee should make special comparative examinations.

In tensile tests the Conventions do not define so definitely as do we the quantities to be measured; they do not give the same limits of approximation in their measures; they follow the law of similarity in adopting cylindrical test-pieces, but use a different coefficient from ours, which tends to give to the useful or test length a greater value for the same diameter. Other differences are apparent in the description of their standard rectangular test-pieces.

The American Society prescribes an invariable standard of test length, independent of both the diameter and the cross section of the test-piece.

The resolutions of the Conventions concerning shock tests are confined almost entirely to finished pieces. They give more explicit directions than do we in regard to the arrangement of the apparatus employed, but certain experiments made upon test-pieces that we have especially studied are not mentioned by them.

In bending tests they recommend that the bending should be done around a mandrel of unvarying diameter, while the American Society claims that the mandrel should vary in proportion to the thickness of the test-piece. The dimensions of their bars differ also from those used by us.

The differences just given are the most marked; but they are in reality of little importance, and probably can be easily overcome.

In the general resolutions concerning the precautions to be observed in preparing test-pieces we find at times differences of detail, but they are usually of minor importance, since the three sets of resolutions upon that subject are inspired by the same general principles.

In so far as the general formulas, as well as the methods of testing referred to above are concerned, we find as a result of this comparison nothing to indicate that the desired unity of method may not be attained should an international commission be called for that purpose.

FIRST AND SECOND PARTS.

PHYSICAL EXAMINATION AND CHEMICAL TESTS.

The resolutions of the Conventions do not contain any specific directions upon those subjects, but they advise the acquisition of as thorough a knowledge as possible of the results of both microscopic and chemical examinations, especially in all cases of scientific research.

According to the recommendations of the American Society, the magnetic condition of a metal should be especially mentioned.

Those recommendations require, moreover, that when in tensile tests the ruptured section presents a cupel form the fact should be mentioned, the relative position of the edges of the cupels with reference to each of the pieces of the tested bar being indicated.

To determine the effects of tempering upon steel, the American Society recommends in addition that the bars should be heated to a bright red and immediately quenched in water at from 32° to 40° F. (0° to 5° C.).

Our Commission requires that the test-bars should be heated to a comparatively deep cherry red and quenched in water at 28° C., the volume of water being great in proportion to the volume of the bars.

The resolutions of the Conventions also require that the metal should be heated to a cherry red (placed by them at from 550° to 600° C.) and quenched in water at 25° C.

They recommend also, as will be seen later on, that copper test-pieces should be heated to 700° C. and quenched in water at 15° C.

That recommendation is not found among our conclusions, which require, however, that deductions from experiments with copper or its alloys shall be drawn from tests made after the last annealing in the manufacture of the plates.

THIRD PART.

MECHANICAL TESTS—RECOMMENDATIONS COMMON TO ALL METHODS OF TESTING.

CHAPTER I.—GENERAL OBSERVATIONS.

Our resolutions show the importance of accompanying mechanical tests of whatever nature with the tensile test; they indicate the approximate exactitude with which one should be content in the majority of current tests, by showing that in practical experiments the exaggerated precision required in scientific research is not necessary. They avoid, moreover, giving any indication regarding a choice between the various methods of testing according to the application proposed.

The resolutions of the Conventions recommend generally that testing should be done with reference to the work to which the pieces are to be subjected; at the same time they indicate which test to adopt and which to reject in specified cases; they advise the adoption of regular tests for certain pieces frequently employed, such as rails, tires, and axles for railroad use, cast or wrought iron, materials for shipbuilding, etc., recommending the greatest possible number of tests upon all pieces of the same delivery, testing without damaging them.

They recommend, for instance, testing tires and axles by shock with a standard impact machine, claiming that it is useless to test tires by a hand hammer or axles by flexure. They add that it may be advisable to have recourse to tensile tests to obtain certain additional complemental information.

They confine themselves to recommending that the degree of exactitude attained in the tests should be stated, or at least that data should be furnished allowing it to be determined.

The resolutions of the American Society recommend that tests should be made as far as possible upon the pieces themselves whose quality it is desired to ascertain, being careful to reproduce as far as possible the conditions to which the pieces will be subjected when in use. They add, with a view to facilitate comparison, that it would be well to make a standard test over and above the tests upon finished pieces.

With regard to registering apparatus, our Commission limits itself to saying that it should be employed without hesitation, as its use even when it is not positively accurate may prevent serious error.

The American Society seems, however, to recommend it more formally, especially for tensile tests.

In regard to test-pieces that are imperfect, our resolutions require that they shall be thrown out of the calculation of averages established from a scientific point of view whenever there are exceptional or local defects in the test pieces.

The American Society remarks on this subject that in making tests all pieces of abnormal appearance or those showing superficial defects should be rejected. If, however, a perfect piece cannot be found, a record of the imperfections should be kept.

CHAPTER II.—PREPARATION OF TEST-PIECES.

CONDITION OF THE METAL.

Our resolutions recommend in general that the condition of the metal employed shall be precisely defined principally with respect to hammer hardening (*écrouissage*)*, and especially when soft metals are used, that the test-pieces shall not be removed until the metal has been brought to the exact condition under which it is decided to test it; they mention also the precautions to be taken in finishing off test-pieces, in order to avoid any strain which might produce a change in the condition of the metal.

The American Society also insists upon the importance of observing its resolutions, which state that the lightest blow from a hammer, or any blow incorrectly given, may falsify results, should the abnormal strain thus produced be greater than that required to cause variation in the quality of the metal to be tested.

They admit, moreover, that soft metals are less susceptible to those influences than hard metals.

With regard to plates of mild steel, the Conventions have decided that it is unnecessary to test them after they have been annealed, as it is too difficult to determine the exact temperature of annealing. They add, in conclusion, and in accord with our Commission, that the object generally sought is to ascertain the nature of the metal in the condition when delivered.

THE PLACE AT WHICH AND THE MANNER IN WHICH TEST-PIECES SHOULD BE CUT—FABRICATION OF TEST BARS.

The resolutions of the Conventions require, for instance, with rails, that the bars detached shall have square † sections and contain the exterior fibres of the rail. Our advice is in general to take the test-bars from the thinnest and thickest parts of the complicated rolled section.

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* Hammer or cold hardening (*écrouissage*) is an alteration produced by working a metal when cold with a hammer, a die, a punch, shears, etc. *Écrouissage* is the standard change in a metal which has been subjected to a permanent deformation at a temperature lower than that required for annealing.

† The original resolutions require only a *rectangular* section.—O. M. C.

With regard to plates, the resolutions of the Conventions are imbued with the same spirit as ours, from which they vary only in minor details. They advise taking the test-pieces from the longitudinal and transverse sides, cutting away, when raw or uncut plates are used, at least 30 millimeters in width from the exterior; when dressed plates are used the test-pieces should be chosen from plane plates of regular thickness.

They admit, without going further into details, that the strips should be cut with shears or by a saw, but for bridge iron or boiler plates they require that the strips cut off by shears shall be straightened out cold by a press, by the use of a wooden mallet, or by small hammers of lead or copper. Before cutting out the test-pieces the strips should be planed down on each side for a width of at least 5 millimeters to do away with the effect of the shears. Upon express demand annealing is permitted for straightening out strips cut by shears from boiler plates.

Our resolutions impose more minute precautions to prevent the deformation of the bars, and if annealing is indispensable for straightening, they require that a temperature of 700° C. shall not be exceeded.

They require also that the test-pieces shall be cut from the strips by a machine, without, however, stipulating that a depth of 5 millimeters in thickness of the metal shall be removed.

For rolled products, the resolutions of the Conventions prescribe that the rough rolled surfaces shall be preserved. Our instructions do not mention that point, but it may be observed that in practice that method is always followed.

The Conventions require, finally, that the reports of tests shall make known the source and the method of manufacture of the test-pieces, and they add that those pieces designed for compression tests should, as far as possible, be smoothed by planing or turning.

In the preparation of test-pieces of copper, they recommend the most minute precautions, which are also mentioned in our resolutions.

Besides those, they add, as has been indicated above, that bars of copper should be annealed at 700° C.* before they are completed, then cooled in the air to a dull red, and finally quenched in water at 15° C., while our resolutions demand that tests shall be made after the last annealing in the fabrication of the plates.

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* That temperature must not be exceeded. *Vide* Original Resolutions.—O. M. C.

In regard to test-pieces of cast iron, the Conventions require that they shall be cast in a mold of very dry sand having an inclination of 10 centimeters per meter.

The entrance for the flow of the melted material should be placed 20 centimeters above the mold, determining thus the length of the runner stick. Those test-pieces should be left with the rough surfaces produced by the molds.

Our resolutions require that for pieces which at some places are more than 9 centimeters thick the test-bars should be cut by a machine from the foot of the runner stick. For other pieces the test-bars may be cast separately, if care be taken to give the mold an inclination of about 20 centimeters per meter and to make the runner stick from 15 to 20 centimeters long.

They always discard the runner stick for bars cast in contiguous pieces.

The American Society remarks, without stating any general laws, that the superficial crust found upon raw materials, either rolled or cast, is either an advantage or a hindrance, according to the work in view, and should therefore be taken into account in the preparation of test-pieces.

CHAPTER III.—STUDY OF THE INFLUENCE OF TEMPERATURE UPON THE RESULTS OF TESTS.

Our resolutions point out the precautions to be observed in making tests at any given temperature, high or low; afterward they deal especially with tests made at ordinary temperatures, remarking that the influence of variations in temperature is felt principally in shock tests, and giving directions for the mitigation of the same.

The resolutions of the Conventions do not contain any directions with regard to those tests; they require that in the cold bending of copper bars the temperature shall not be less than 10° C.

CHAPTER IV.—STUDY OF THE INFLUENCE OF DURATION.

Our Commission gives no positive rule with regard to the effect of the duration of test, considering that the subject is not as yet sufficiently understood; it recommends, however, the continuance of study upon that subject.

The Conventions declare for their part that the influence of time is incontestable, especially in tracing the diagrams in tensile tests, but they conclude that as yet they have not sufficient ground for establishing any fixed velocity of testing iron, copper, and bronze.

On the other hand, in cold-bending tests they claim that the duration is of no importance. In operating upon heated materials they require that the tests shall be made as rapidly as possible, but this is doubtless in consideration of the cooling of the bar.

The American Society requires that the duration of tests shall be noted.

CHAPTER V.—GENERAL OBSERVATIONS UPON TESTING APPARATUS.

APPARATUS OPERATING BY GRADUAL ACTION.

MACHINES FOR TENSILE TESTS.

The Conventions confine themselves to demanding that machines properly handled shall not produce any shock on the test-pieces. They sanction the use of machines operated by hydraulic pressure or by a screw. They add that the test-pieces should be so mounted that the strain of tension or compression shall be uniformly distributed throughout the cross-section.

Besides those requirements, which coincide with those of our Commission, the Conventions include in their resolutions more explicit directions as to the mode of fastening the test-pieces for tensile tests than do we.

For cylindrical test-pieces they propose the use of spherical bearings, preferably in one piece.

They agree that test-pieces of rectangular cross-sections shall be held at each extremity by a bolt passing through a slot provided for the purpose, or that the pieces shall be provided with milled heads and clamped by proper wedges

They forbid positively the use of the serrated wedges used by us, and that point should be submitted to a renewed examination by us.

This last resolution is also adopted by the American Society, which, moreover, recommends in positive terms the use of two special types of attaching apparatus in use in the United States.

With regard to round test-pieces, the American Society proposes to prolong the cylindrical section by conical bearings resting upon the clamping pieces, in preference to threaded ends, such as are often used. This form is recommended for all metals except copper and its alloys, for which the Society considers it as yet impossible to give any standard type, conclusive experiments being lacking.

MACHINES FOR PRESSURE TESTS.

The Conventions in their resolutions are in almost perfect accord with us upon this subject. They require that the strain shall be carefully distributed throughout the cross-section, and point out that to attain such a result it is well so to place the pressure plates that at least one may move easily and freely in all directions.

Those resolutions recommend, moreover, the use of very smooth test-pieces; in other words, those which have been planed or turned; but this recommendation has reference only to the bearing surfaces, since in speaking of castings they require besides that the faces of test-pieces for flexure and compression shall be left in the rough state.

The American Society requires that the pieces to be tested shall be placed in position without the aid of any intervening medium whatsoever, such as wedges, supporting discs, etc., and that they shall be brought exactly into the axis of strain. That Society repeats that the test-pieces should be prepared with the utmost care, the bearing surfaces being exactly parallel and normal to the axis.

Whenever tests are made upon large pieces horizontally placed it is necessary to take into account the initial flexure due to the weight of the piece as held in place.

MACHINES FOR TRANSVERSE, FOLDING, BENDING, AND CURVING TESTS.

The Conventions confine themselves to recommending slow-moving apparatus, acting either by pressure on the middle between two supports or by lateral pressure brought to bear upon one part of the test-piece, while the other is securely held by clamping. Such apparatus should be simple and capable of being used rapidly. The weakest part of the test-piece should be clearly visible.

For folding, they simply indicate that it should be done in a continuous manner, and that if a mandrel is used it should be of the smallest possible diameter, recommending in certain cases one with a fixed diameter of 25 millimeters. They repeat, moreover, that the angle of bending is not alone sufficient to indicate the deformation, but that the radius of external curvature must be taken into account.

The American Society recommends the use of a very simple apparatus for making bending tests upon mandrels of varying diameter, and prescribes tne use of the hand vice for bending, which is accepted by us, however, with certain restrictions.

For transverse tests that Society advises that supporting wedges shall not be used, preferring rolls that shall be displaced in proportion to the deformation by flexure of the bars.

The foreign resolutions do not point out the different modes of testing by bending that are specially defined by our Commission, but the Conventions state that the permanent committee should seek to determine, in the comparative tests remaining to be executed, the best method of measuring deformations.

MACHINES FOR TORSION TESTS.

According to our conclusions, those machines should be arranged in such a manner that the axis of the piece will not sustain any flexure.

The resolutions of the Conventions give no data upon this subject, but the American Society has given definite instructions tending to prevent the production of any disturbing strains, such as transversal flexure or longitudinal tension over and above torsion properly so-called. To this end the collars which hold the test-pieces should be exactly concentric with it, to avoid giving any but a tangential strain.

APPARATUS OPERATING BY ABRUPT ACTION.

The resolutions of the Conventions are generally in harmony with ours in principle, but they give much more explicit directions for the setting up of testing hammers, especially in the case of heavy machines intended to test whole pieces. They have adopted for this purpose, as a standard type of hammer, one weighing 1,000 kilograms, permitting in certain exceptional cases the use of one weighing only 500 kilograms, and they have decided that every hammer of the standard type shall be stamped and officially registered. They require that the studies relating to the question of shock tests shall continue, and they have charged the permanent committee with collecting all new propositions relating to the installation of machines for shock tests.

They accept hammers as we make them, of cast iron or of cast or forged steel; they add that the striking surface should be of forged steel, finished by dove-tailing and made secure by wedges in such a manner that the vertical centre of gravity of the whole may not be disturbed.

This vertical should coincide with the axis of the leads and should be indicated by marks upon the anvil or the anvil block. The proper arrangement of the striking surface should be verified by means of suitable reference points.

We require, moreover, that the mass and shape of the hammer shall be perfectly symmetrical with respect to the plane of the leads.

Our directions, more especially with reference to tests upon test-pieces, regulate the form of the face of the small hammers used, and they indicate even the radius of curvature to be given that face, depending on the kind of metal to be tested. They also give the different weights for such hammers used under similar circumstances.

According to the resolutions of the Conventions, the guided length of the hammer should be at least double the clear width between the guides; we claim, however, only that it should be greater than the width between the guides.

The Conventions require that the weight of the anvil block shall be at least ten times that of the hammer, and that the foundations shall be inelastic. We require that the anvil block shall constitute, either alone or embedded in solid masonry, a solid mass from fifteen to twenty times heavier than the hammer.

In the working of the detaching apparatus the Conventions agree with us that there should be no wedging. The Conventions advise the placing of the point of suspension upon the same vertical as the centre of gravity of the hammer, and to intercolate between the detaching device and the hammer a short flexible piece—for example, a chain or cord. They point out as a style to be recommended the detaching device adopted in Russia, which, however, from the sketch given, does not seem to be provided with an intermediate chain or cord.

In regard to the friction on the leads, they recommend that those leads should be lubricated with plumbago. They reject all apparatus having a work due to friction greater than 2 per cent. of the useful work. They describe a process of measuring friction by intercolating a spring balance between the hammer and its lifting rope. They propose to deduce the effective weight of the hammer from the effect produced, with a given height of fall, on a centrally mounted standard cylinder made of copper, of dimensions yet to be determined.

For the height of fall they advise that 6 meters shall not be exceeded, as the setting up of hammers of greater height cannot be done with as much security or exactitude. They recommend the use of a sliding scale for measuring the effective work, so that the zero of the graduation may be set at the top of the piece to be tested. That scale should be divided into metric half tons.

All of the recommendations of the Conventions with regard to the setting up of machines for shock tests are agreed to by the American Society; the weight of the hammer and the height of fall are determined by the measures in use in America. The weights adopted are, respectively, 1,000, 1,500, and 2,500 pounds for testing large pieces (equal to 453, 653, and 907 kilograms), and the height of fall is fixed at 20 feet (equal to 6.09 meters), allowing, however, without doubt, the adoption of a less height of fall in special cases.

CHAPTER VI.—EXAMINATION OF THE FORCES TO BE MEASURED.

Our resolutions recommend in effect that the strains and deformations produced in all tests by continuous action shall be measured; these form of necessity two great classes—the one of elastic and the other of permanent deformation.

Concerning the period of elastic deformation, three limits of elasticity are distinguished and defined, viz., the theoretical, the proportional, and the apparent. Concerning the period of permanent deformation, our resolutions define the maximum load supported, and the load of rupture, properly so-called, giving the deformation corresponding to each of those two loads.

Neither the resolutions of the Conventions nor those of the American Society give any instructions common to all tests made by gradual action; they restrict themselves entirely to tensile tests.

The Conventions require that during the elastic period there shall be sought the yield point and the limit of proportional elongation, appearing at the same time to admit that those two limits are blended, and during the period of permanent deformation the maximum resistance and the beginning of contraction as well as the load of actual rupture with the corresponding section.

The American Society requires the determination of the same information, excepting only the beginning of contraction, insisting especially upon the importance of the yield point, which measurement it claims should be made with the greatest precision.

It defines that limit as being the load which produces a modification in the rate of elongation, which would seem to identify it with the proportional limit; but further on, in an annexed illustration, it requires that the limit shall be determined by noting the point at which the elongation is suddenly augmented, which brings us back to the apparent limit.

The recommendations of that Society prescribe, moreover, the measurement of the elastic elongation with a view of determining thereby the modulus or coefficient of elasticity, and they point out, to this end, a special process consisting of measuring the elongations between certain limiting loads, determined in advance.

They also observe the smallest section of the test-piece under the action of the elastic limit (yield point), and, after the test, the section of rupture.

In the calculation of the strain brought to bear upon the unit of section, their resolutions add that it is necessary always to consider the initial appearance of the test-piece, and not the constantly-changing appearance under the different loads that it supports up to the limit of rupture.

This resolution conforms with that of our Commission. However, as in experiments made upon copper and brass, a comparison of the loads developed in the course of the tests with the corresponding deformations has given rise to interesting conclusions, our Commission has expressed the hope that analogous studies shall be made in regard to iron and steel.

CHAPTERS VII AND VIII.—MECHANICAL AND TECHNICAL TERMINOLOGY.

Those two questions have been examined by our Commission only, but we have not been able to establish any fixed laws in regard to them. They have not been considered by either the Conventions or by the American Society.

FOURTH PART.

DETAILED STUDY OF THE DIFFERENT METHODS OF TESTING.

FIRST CLASS.—METHODS OF TESTING BY GRADUAL ACTION.

Our Commission states in a general way that those tests should be made in a manner as continuous and as regularly progressive as possible, and that recommendation is in accord with that adopted by the Conventions with regard to tensile tests.

The American Society agrees to this also in a general way, but it provides for stopping the strain at certain intervals, whenever it is necessary to make observations of deformation, which is the case, for instance, in measuring the elastic limit and the elastic elongation.

The Society requires in such cases that the developed strain shall never be diminished, but that it shall be maintained continuously in action.

CHAPTER I.—TENSILE TESTS.

MEASURE OF STRESS AND ELONGATION.

Our resolutions define the precision to be sought in the definition and scientific observation of the first two elastic limits previously described; they point out that for such purpose the elongations should be measured to the nearest thousandth of a millimeter.

Such precision is unnecessary for the determination of the third limit, called the apparent limit, or the beginning of great deformation under a constant load.

Regarding the observations made during the period of permanent deformation, our Commission recommends that the maximum load that can be borne shall be measured, saying that it does not appear to be necessary to measure the load of rupture, while, as has been shown heretofore, this measurement is required by the Conventions and by the American Society.

In regard to measuring elongation, our Commission believes that for current practical tests on products of the same well-known make it is sufficient generally to measure the total elongation after rupture; but in more exact tests it would be useful to make some special experiments with a view to determine the relative value of the different parts which compose the total elongation (distributed elongation and elongation of contraction).

The foreign resolutions do not consider this distinction. They recommend simply a method of measuring the total elongation suitable for reducing the results to uniformity by disregarding the influence that the position of the section of rupture beyond the middle of the test-piece may have upon the effective length of the observed elongation. This method amounts in principle to doubling the measured elongation for a distance equal to one-half the length of the test-piece, counting from the section of rupture on the side, where it is possible to measure it, in such a manner as to render the same conditions as would have obtained had the rupture occurred in the middle of the test-piece and had the elongation been produced freely on both sides. The result is to increase a little the effective elongation measured directly on the real test-piece.

This method is inconvenient in that it is necessary in advance to divide the useful or test length into very small sections. The length of each section is fixed at 1 centimeter in Germany and at a half or even a quarter of an inch in America (12 or 6 millimeters). As the elongations during the course of the test are produced in a comparatively irregular manner upon the length of the test-piece, we may consider that they are not necessarily uniform at the ruptured section even when that is in the middle of the piece, and the method can give in this respect only approximate results.

It is true that if recourse to that method is not desired it will be found necessary, according to our resolutions, to discard every test-bar whose elongation of contraction is not integrally included between the reference points; the resolutions of the Conventions, particularizing still further, give this same injunction when the section of rupture falls beyond the middle third of the useful length.

In regard to tensile diagrams, our resolutions declare that it does not seem necessary to have recourse to them, at least in current practical tests with a view to ascertaining the quality of the metal tested from a determination of the useful surface they present.

The resolutions of the Conventions provide, however, for the use of diagrams, and require that their area shall be calculated up to the limit corresponding to rupture. They observe on this subject that without doubt, in principle, the work on the test-piece should be considered only up to the beginning of contraction, but that in most cases the work corresponding to that last period is of little importance, and the error thus produced cannot be very considerable. In cases where the diagram is not made by special apparatus, they advise making as many observations as possible during the test in order to trace the diagram by separate points.

The resolutions of the American Society also provide for the use of such diagrams.

With regard to the varying coefficients thus far proposed, our Commission finds it impossible to recommend them, and, moreover, the foreign resolutions make no mention of them.

In regard to the precision to be sought in measuring strains and elongations, our Commission declares that for strains less than 5,000 kilograms a determination to within 25 kilograms is sufficient, going up to the limit of 50 kilograms, when the strain exceeds 5 tons; or, for the first class, to within one two-hundredths, and for the second to within less than one one-hundredth of the total sum.

The Conventions state that on their part they will accept an error of one-tenth of a kilogram per square millimeter for tensile strains corresponding to the elastic limit (yield point) and to that of rupture, which leads in practice, especially for the load of rupture, to a much smaller proportion of error than we have permitted.

The American Society makes no recommendation upon this subject.

In measuring the dimensions of test-pieces and elongations our Commission recommends a determination to within five one-hundredths of a millimeter in the case of dimensions equal to or less than 10 millimeters, and it accepts an approximation to within one-tenth only when the length to be measured is greater than 10 millimeters; the limit is, therefore, to within more than five one-thousandths in the first case, and to within less than one one-hundredth in the second.

The resolutions of the Conventions recommend a degree of precision reaching one one-thousandth in measuring the elongation of rupture, and of one one-hundredth in measuring the contraction of area (considered, no doubt, as being the section of rupture itself).

They recognize, however, that in many cases these decimals are uncertain, and that it is not necessary to add others. They state that it is sufficient to take the dimensions of test-pieces to within one-tenth of a millimeter, which, considering the measurement of the thickness and the width of the section, gives a degree of precision inferior to that recommended by our Commission.

They require that the elongation shall be measured on two diametrically opposed sides of the test-bar, in order that the mean may be taken of the sum of the lengths obtained by measuring upon each part respectively the distance comprised between the corresponding reference point and the section of rupture.

For rectangular test-pieces it is even proposed to make three measurements of elongation, taking them upon the two sides and upon one of the faces. The mean of the first two measures should be given and the last one should be stated separately.

The General Report of our Commission only mentions the use of elasticimeters, which are considered almost indispensable in determining the elàstic limit (yield point), but which seem less necessary for the simple measurement of the total elongation.

With the aim of measuring the section of rupture with all possible precision our resolutions propose that the measurement of the dimensions shall always be made at two opposite points, and that there shall be considered either the circle of mean diameter or the rectangle of mean dimensions, according as the test-pieces have circular or rectangular sections.

DIMENSIONS OF TEST-PIECES.

In order that the proximity of the heads shall not interfere with the observed results, especially in the measurement of elongation, our resolutions require that the distance from the springing or end of the heads to the reference points must be equal at least to the diameter or to the greatest side of the transverse section of the test-piece; they consider that under such conditions the form of the heads is not important.

The Conventions limit themselves to remarking that for cylindrical test-pieces the actual length of the cylindrical part should exceed the test length by at least 10 millimeters,* which may be interpreted, doubtless, as imposing a uniform minimum of 5 millimeters of waste length at each end, regardless of the diameter of the test-piece, which may be 10, 15, 20, or 25 millimeters.

The American Society gives regulations analogous to those of the French Commission. It requires that with round test-pieces the distances reserved beyond each reference point shall be equal to or greater than a diameter. For flat or built-up square test-pieces its regulations require once and a half the width of the section or the side of the square.

In order to make a comparison of the total elongations, taken after the rupture of circular test-pieces of different design, our Commission has decided to establish a fixed relation between the transverse section and the useful or test length of the test-piece. This relation deduced by the law of similarity shows that the test length should be proportional to the square root of the cross-section, and that fundamental law has been admitted also by the Conventions. The only difference is in respect to the value of the coefficient adopted.

While our formula

$$\Lambda^2 = 66\ 67\ \Omega$$

$$\text{or}\quad \Lambda = 8.16\sqrt{\Omega}$$

results in giving a diameter of 27.64 millimeters to a test-piece, having a test length of 200 millimeters, the formula of the Conventions

$$\Lambda = 11.3\sqrt{\Omega}$$

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* The original resolutions require that the actual length shall exceed the test length by 20 millimeters.—O. M. C.

leads to a smaller diameter for the same test length, for it gives in fact a diameter of 20 millimeters to a test-piece 200 millimeters long. In a general way this formula recommends itself on account of its great simplicity, inasmuch as the calculation of the linear dimensions is immediate; the useful or test length amounting always to ten times the diameter.

Our formula presents, on the other hand, the advantage of expressing the area by a simple number, for example, 600 square millimeters for a test-piece 200 millimeters in length, considering that it is better to seek simplicity in expressing the cross-section rather than in indicating the diameter, because no matter what number expresses the diameter, the difficulty of measuring it is always the same, whereas it is only the section which intervenes in the calculations, and the adoption of a simpler number to express the section greatly facilitates such calculations.

Notwithstanding the employment of the law of similarity, the two resolutions preserve well-defined normal types, to which they recommend that reference be made. These are four in number in the two cases.

Our standards have, respectively, test lengths of 70, 100, 141, and 200 millimeters; cross-sections of 75, 150, 300, and 600 square millimeters, and diameters of 9.77, 13.82, 19.55, and 27.64 millimeters. The standards of the Conventions give sections very closely resembling these, but their longitudinal dimensions are greater; they have lengths, respectively, of 100, 150, 200, and 250 millimeters for diameters of 10, 15, 20, and 25 millimeters.

Those standard types are adopted for steel and iron, as well as for copper and its alloys; for castings, however, the Conventions prescribe test-pieces having a diameter of 25 millimeters, and a useful or test length of 200 millimeters.

The American Society prescribes four standards with diameters, respectively, of 0.4, 0.6, 0.8, and 1 inch, which equals 0.010, 0.015, 0.020, and 0.025 millimeter, but it preserves a constant useful or test length of 8 inches (0.2 meter), ignoring the differences which must occur in the measurement of total elongation by testing with a uniform length and a variable diameter.

The test length of 8 inches, as well as the various diameters given, have been chosen, moreover, for the purpose of approaching as nearly as possible the measures of the metric system, counting 8 inches as equal to 200 millimeters. This is expressly stated by the Society itself.

The law of similarity thus admitted, as has been shown, for cylindrical test-pieces, is extended by our Commission, with the same coefficient, to test-pieces of square cross-section, and even to pieces that are simply rectangular, observing carefully certain restrictions established with a view to facilitate manufacture, by establishing different series, in each one of which the width remains the same.

The Conventions also extend the formula expressing the law of similarity to test-pieces of simply rectangular cross section, but without introducing any definite restrictions. They recommend, however, that the section 30 by 10 shall be considered as the standard, even when the breadth and thickness may be chosen at pleasure.

When the thickness is given, as for plates, and when it does not exceed 24 millimeters, a width of 30 millimeters should be adopted.

Whenever the thickness exceeds 24 millimeters it should be considered as breadth, and a thickness of 10 millimeters should be given to the test-piece.

When the testing machines are not sufficiently powerful, the limit of 24 millimeters should be replaced by that of 16 or 17 millimeters.

The American Society permits on its part a width of 1.2 inches (0.030 meter) for rectangular test-pieces having a thickness of less than 1 inch (0.025 meter).

If the thickness reaches 1 inch the measure of 0.8 inch (0.02 meter) will be taken for the width.

In testing sheets and plates the crust produced in rolling should not be removed.

In testing sheets there should be taken two samples having the total section of the bar.

Besides the preceding rules just given, which are considered applicable only to rectangular test-pieces having a thickness of more than 5 millimeters, our Commission has adopted special dimensions for test-pieces having a thickness of less than that figure, considering that it is not necessary to be guided by the law of similarity, because that law is doubtless no longer applicable in such a case.

The useful or test length of those thin test-pieces has been fixed uniformly at 100 millimeters, without reference to the thickness or the nature of the metal to be tested.

CONDUCT OF TESTS.

Our resolutions recommend, as has been indicated, operating by progressive or gradual tension. This recommendation is also found in the resolutions of the Conventions, but the American Society permits interruption of the test, without relieving, however, the action of the strain, for the purpose of making certain important observations during the course of the test, such as those relating to the elastic limit (yield point).

In general, the American Society recommends the utmost care in placing the test-pieces, so that they may be directly in the axis of the machine, and to this end it advises that it should be referred carefully to two normal planes intersecting each other in line with this axis.

The Society also recommends placing test-pieces for tensile tests under a very slight initial strain (from 0.7 to 1.4 kilograms per square millimeter) before commencing observations, in order that the errors generally made at the beginning of a test may be avoided.

In regard to the rate of testing, our Commission has confined itself to giving some approximate directions, and it observes, to that end, that the duration of a test, which should be in a certain measure a function of the volume of the test-piece, should be comprised between one and six minutes for current tests on test-pieces of ordinary dimensions. This time may be reduced to thirty seconds for small test-pieces having a thickness of less than 5 millimeters. Care should be taken, especially with soft metals, to avoid heating the bars.

The foreign resolutions make no recommendations upon this subject. The Conventions, however, observe that in establishing the diagram of tensile test great importance should be attached to showing with what rapidity the diagram was traced.

CHAPTER II.—PRESSURE TESTS.

TESTS ON SHORT PIECES.

For determining the elastic limit our Commission advises the employment of cylindrical test-pieces having a diameter of 27.65 millimeters (600 square millimeters in cross-section) and 100 millimeters of useful or test length; but for the determination of the maximum resistance to compression or crushing the diameter of the standard test-pieces will be reduced to 19.56 millimeters (300 square millimeters of cross-section), and the useful length to 20 millimeters.

The regulations of the Conventions propose in testing castings the use of cubes of 25 millimeters a side, making them serve as samples for pressure tests. In another passage, however, they recommend a height of 30 millimeters.

They give no complementary information on the subject of that test, merely stating that Wachler adopted 25 millimeters as the standard dimension in his studies.

The American Society considers that pressure tests upon short test-pieces are of little interest, recommending, preferably, the adoption of pieces of a length of from 10 to 20 diameters.

However, when it is a question of determining the resistance to disaggregation, the use of cylinders 1 inch in diameter (0.025 meter) and 2 inches in height (0.050 meter) is proposed. Whenever the elastic resistance is to be determined the height will be increased to 10 or 20 inches (0.254 meter or 0.508 meter), always keeping the useful or test length at 8 inches, as in tensile tests.

TESTS ON LONG PIECES (FLAMBEMENT).

Our Commission insists especially upon the interest of making buckling tests, stating that for iron and steel the resistance determined by the tests thus made is in no way proportional to that determined by tensile tests, and in the existing state of science cannot be deduced from the results obtained by the usual tests.

The Commission declares that the tests can be made on riveted pieces or on bars cut up for this purpose, and it observes that to render the two tests comparable it is sufficient that the ratio of the length of the test-piece to the minimum radius of gyration of the section should have the same value. In tests upon test-pieces, the Commission proposes to give to that ratio values which are multiples of 5 or 10.

It recommends that those tests shall always be made under well-defined conditions, such as those by perfect hinging or complete clamping. The precautions to be observed in the first case are prescribed, but it is added that no satisfactory disposition for such testing by clamping is yet known.

The foreign resolutions give no particular instructions regarding pressure tests on long pieces. However, the American Society provides for tests upon pieces having a diameter of 1 inch and from 10 to 20 inches long for determining the elastic limit (yield point).

It requires that the process shall be the same as in tensile tests, dividing the useful or test length into small sections in such a manner that the loss in value sustained may be determined from its elements, and that the calculation of the modulus and the coefficient of elasticity shall be made under like conditions.

CHAPTER III.—TRANSVERSE TESTS.

TESTS ON TEST-PIECES.

CASTINGS.

Our Commission adopts for standard bars a section having a side of 40 millimeters, indicating that the total length should be determined in such a manner as to give a useful or test length of 150 or 500 millimeters according to the apparatus used (Monge or Joëssel balance).

The Conventions have adopted a prism 3 centimeters on a side, with a total length of 110 centimeters, giving a useful or test length of 100 centimeters. They recommend measuring the resistance to flexure up to the point of rupture and the corresponding work on three test-pieces. The faces of the pieces should be left in their rough condition.

Our Commission prescribes that the faces of the bars shall be shaped by a machine and the edges rounded by a file. It regulates finally the duration of the test, which should be comprised between one and two minutes.

The American Society requires for scientific tests that the effect of superficial quenching shall be avoided by using bars measuring at least 2 inches on a side (0.050 meter) or 2½ inches in diameter (0.063 meter). In current practical tests there will be used bars measuring only 1 inch (0.025 meter) on a side, taking the necessary precaution to throw aside surfaces which have been hardened or marked with blow holes.

STEEL PLATES FOR SPRINGS.

Our Commission fixes the length to be adopted for developed test-bars at 1 meter, the section to be used, however, being preserved without any modification.

The plate will be prepared under the same conditions as to quenching and annealing as the springs.

For testing it will be placed on two movable slides, the use of which is also recommended by the American Society.

The test will be continued without stopping or lessening the load and with a regular and continuous movement up to the limit fixed upon, in such manner that the duration of the whole test is comprised between two and five minutes.

The foreign recommendations contain no special remarks upon that subject.

The American Society recommends, however, in a general way, regarding transverse tests, that the sample should be placed firmly in a horizontal position to avoid supporting wedges, that the strain shall be brought to bear exactly in the middle and normal to the axis of the piece, and in a plane passing through the three strained points. It requires that the bars used shall be 1 inch (0.025 meter) on a side, have a length of 40 inches (1.016 meters), and that they shall be placed upon supports 36 inches apart (0.914 meter).

According to the resolutions of the Society the deviations should be measured from a fixed and invariable base. It is well to determine them at points situated at stated intervals from the middle of the bar in such a manner as to obtain certain elements of the curve of flexure over the whole extent of the length, and especially in the vicinity of the elastic limit (yield point).

Certain values of the permanent deviation may also be determined.

TESTS ON FINISHED OR WHOLE PIECES.

SPRINGS OF PARALLEL AND SPIRAL PLATES.

Our Commission recommends in transverse tests that springs be subjected to a less strain than that which corresponds to permanent deformation.

The American Society, on its part, proposes to apply the maximum working load, and to determine the deviation produced by that test. The test load will be obtained by proceeding by pressure or by shock, according to circumstances, but it will be applied only once.

RAILS AND FISH PLATES.

Our Commission recommends determining as nearly as possible the load corresponding to the proportional limit of elasticity in testing those pieces; it adds that the duration of the tests should be comprised between two and five minutes.

The foreign resolutions examine also the question of transverse tests by static pressure, requiring that they shall be considered from the two following points of view: First, there will be determined the elastic limit (the point where the set becomes permanent); second, there will be measured the flexibility under increasing loads, exceeding even the elastic limit.

The American Society states that it is hardly practicable to subject either rails or axles to a transverse test by static pressure.

CHAPTER IV.—FOLDING, BENDING, AND CURVING TESTS.

Our Commission proposes to adopt for those tests standard bars 40 millimeters wide and 250 millimeters long, observing that the length may be reduced to 150 millimeters for copper and its alloys. It recommends, besides, that those various tests shall be made by a machine so arranged as to produce a slow, progressive strain, and that in folding tests the initial fold shall be obtained with a radius of curvature differing as little as possible from that exacted for the limiting fold.

For mechanical folding the use of the hydraulic press or hammer is recommended.

Our Commission gives, besides, certain directions for folding done by a hand vise. It is necessary to observe here that this mode of testing is prohibited by the American Society.

In regard to bending tests, our Commission has not yet fixed upon any stated diameter for the mandrel.

For curving tests it proposes to adopt such machines as will permit the measurement at each instant of the developed strain and the corresponding deformation.

The Conventions recommend, as has been indicated, the use of slow-moving apparatus, acting either upon the middle or at the extremity of the test-bar, but they require especially bending around a mandrel for the hot and cold folding test of irons and steels of all kinds, fixing upon a diameter of 25 millimeters for mandrels to be adopted in the case of wrought or cast iron for bridges and of boiler plates more than 6 millimeters in thickness. The mandrel should not be removed during the test until the ends of the test-pieces have become parallel to each other, and the bending will be continued to the point of contact in the case of test-pieces of copper.

They add that the test-pieces employed should have a rectangular section, the width of which should be three times the thickness, and that the edges should be slightly rounded.

They observe, besides, that the angle-folding alone is not sufficient for judging of the degree of deformation of the test-piece, but that it is also necessary to take into account the radius of external curvature. They propose to make this measurement direct by means of templets, or to deduce it from the measure of the elongation upon the exterior face.

They require, finally, that the permanent committee shall search for the most convenient method of measuring deformations, and they also require that it shall look into folding tests made upon defective pieces.

The American Society also recommends the bending test around a mandrel, but it prescribes the use of mandrels of variable diameters, and it recommends giving them a diameter equal to twice the thickness of the bar to be tested.

It approves, finally, the use of a very simple apparatus which shall permit that test to be made rapidly. It fixes 1 inch (0.025 meter) as the standard width to be given test-pieces for folding tests.

CHAPTER V.—TORSION TESTS.

Our Commission confines itself to expressing the hope that experiments shall be continued with regard to the study of torsion.

The American Society has given certain instructions, previously indicated, with regard to the installation of apparatus to be used in those tests.

With regard to test-pieces, it recommends the use of cylindrical heads, prohibiting absolutely square-shaped heads. It gives a sketch of the position to be given the fastenings, and it demands that the distance between the head and the nearest point of reference shall not be less than one diameter.

It gives nothing concerning the determination of the useful or test length.

CHAPTER VI.—MIXED TESTS (SHEARING AND PUNCHING).

Our Commission has expressed the wish that the study of those tests may be continued, and it has proposed certain recommendations which may serve as a beginning for subsequent regulation.

The resolutions of the Conventions say nothing upon this subject; they recommend only that certain plates, like those of wrought iron for boilers, shall be submitted to the punching test, but they claim that the test is useless for plates of mild steel or ingot iron, which should never be punched.

The American Society remarks that in this test special care should be taken to determine the space to be reserved between the edge of the finished bar and the edge of the hole punched in the interior of the section, in order that cracks may not be formed.

This question is being studied by numerous experts both in France and in America.

SECOND CLASS.—METHODS OF TESTING BY ABRUPT ACTION.

Our Commission, in common with the foreign resolutions, indicates the particular interest to be found in shock tests, for they give information which gradual action cannot furnish. It recommends that study concerning tensile tests by shock and the use of explosives may be continued.

CHAPTER I.—TRANSVERSE TESTS BY SHOCK.

Our conclusions relate especially to tests on test-pieces, as has been shown above. They fix the dimensions to be given to test the bars, according to the nature of the metal tested, regulating under the same conditions the weight of the hammer, the form of the striking face, and that of the edges of the supports.

They recommend, besides, a continuance of theoretical research, to ascertain the respective effects of the two elements which are the component parts of the energy of shock, namely, the weight of the hammer and the height of fall. They require that for each metal there shall be determined the height of fall above which the fragility increases rapidly, that there shall be studied the effect of constantly increasing heights of fall in ordinary transverse tests made on test-pieces resting upon two supports, and finally that there shall be studied tests made by bringing the shock to bear upon the free end of test-pieces clamped at one end only.

Those different subjects are not examined in the foreign resolutions, which give special attention to tests upon whole pieces, and determined, as has been indicated, the weight of the hammer and the height of fall to be used.

In tests upon finished pieces the resolutions of the Conventions recommend the use of bearing blocks or caps of such form that the upper surface of the piece shall be perfectly horizontal, the face of the hammer being always perfectly smooth and plane. Those pieces should be as light as possible.

Our Commission appears to think, however, that the use of those caps may be dispensed with when it is a question of testing pieces before sustaining in service blows which would be of such a character as to alter them.

In a paper on shock tests, presented to the American Society at its meeting of August, 1894, in Brooklyn, by Mr. Mansfield Merriman, Vice-President of the Society, the author recommends the disuse of those caps; he proposes to give the hammer a large striking surface to avoid loss of energy by heat, and to take account of the rebound of the hammer.

The Conventions claim, on the other hand, that the data derived from tests thus far made are not sufficiently conclusive to admit of giving any fixed form for either the supports or the pieces destined to receive the shock.

In observations on the results, they declare that it is sufficient to determine the curvature deflection to within about 1 millimeter, when it is measured on a cord of from 1 to 1.5 meters in length.

In a general way they recommend, as has our Commission, the taking of careful notes regarding all the peculiarities of the test, stating, for example, whether there had been any interruption during the test, whether the pieces had been turned over, etc.

CHAPTER II.—SUPERFICIAL PENETRATION TESTS BY SHOCK.

That mode of testing, minutely studied by our Commission, has not been examined in the foreign resolutions.

CHAPTER III.—PERFORATION TESTS BY SHOCK.

Our Commission has only been able to express a desire that new experiments should be made for the purpose of solving the various questions which have been brought up by that method of test. The study of that method of test has not, as yet, been broached by the Conventions or by the American Society.

THIRD CLASS.—STUDY OF HARDNESS AND FRAGILITY.

CHAPTER I.—PROPOSED DEFINITIONS AND METHODS OF MEASURING.

Our Commission has reserved the study of that subject for a future session.

CHAPTER II.—TESTS OF HARDNESS BY SCRATCHING AND BY RESISTANCE TO WEAR AND TEAR.

Our Commission has expressed the hope that those two subjects might be the object of complemental studies.

The Conventions have expressed a like hope in reference to the wear and tear of rails and tires, requiring that those tests shall be made under conditions as nearly like those of practice as possible.

The American Society declares that it is impossible to present any recommendations upon that subject; however, it points out that for rails it is proper to make tests upon curved pieces, and to take into consideration the action of shock, of rapid rolling, and of variations in temperature and humidity.

CHAPTER III.—FOLDING TESTS AFTER COLD HARDENING BY PUNCHING, OR AFTER CUTTING.

The Conventions have charged the permanent committee with searching for the causes of irregularities in ingot iron shown by unexpected breakages, notwithstanding tests upon the broken pieces had given satisfactory results.

Our Commission considers that folding tests made after cold hardening (*écrouissage*) or cutting should show those irregularities, and it has given in this respect certain practical rules which may in some measure bring out the information desired by the Conventions.

FOURTH CLASS.—TESTS OF MANUFACTURE.

CHAPTER I.—COLD WORKING TESTS.

The enlarging upon the mandrel, the heating, the flattening, and crushing tests, all studied in our resolutions, are not mentioned by the foreign resolutions.

CHAPTER II.—HOT WORKING TESTS OF IRONS AND STEELS.

TESTS BY BENDING AND FOLDING.

Our Commission points out certain tests to be made on plates, angle iron, and facing iron; for bars cut from plates the same dimensions are assumed as for cold folding.

It points out that all these tests should be made at the same heat.

The Conventions recommend that certain kinds of metals, such as ingot or wrought iron for bridges, and plates of ingot iron or mild steel for boilers, shall be subjected to the hot folding test. For the latter a test will also be made after quenching. The hot test is made around a mandrel under the same conditions as in cold bending.

TESTS BY STAMPING, BENDING INTO HOOKS, BORING, PRESSING, FORGING, FLATTENING, AND WELDING.

The greater part of those tests are not mentioned in the foreign resolutions, except those by flattening and welding.

The Conventions recommend those two modes of test for different kinds of metals without trying to establish any definite rules.

They declare that it is difficult to generalize from tests by welding, since much depends upon the skillfulness of the operator, and they have determined to require a sub-committee to study the utility of the various hot tests.

The American Society requires recourse to be had to the flattening test for testing riveted bars, and it states, as does our Commission, that the amount of spreading out obtained before the appearance of fissures furnishes one measure of the quality of the metal.

It insists strongly on the welding test, stating that such a test has a special importance in the United States, inasmuch as welded pieces are frequently used there.

It gives the precautions to be observed in welding, which should be done at one temperature, a white heat, and it requires that after the operation the test-piece shall be submitted to a tensile test.

Another sample should be submitted to a folding test after a groove has been made of a depth equal to that of the weld.

The American Society demands that the welded bars shall be allowed to cool without being wet.

It does not prescribe the boring or piercing test after welding recommended by our Commission.

FIFTH CLASS.—SPECIAL TESTS ON CERTAIN FINISHED PIECES.

The foreign resolutions insist strongly upon the great interest that there will be in being able to make tests upon the finished pieces themselves; they require that in setting up testing machines the possibility of making tests on finished pieces shall be kept in mind. They add that the shock test is generally the most important, and for certain pieces in frequent use on railroads they recommend or prescribe certain special tests.

Our Commission, however, does not feel at liberty to formulate any such resolutions, and in making its studies of tests on finished pieces it confines itself to pointing out the method of executing the tests without indicating that any one may be superior to the others.

CHAPTER I.—TESTS ON WIRE.

Our Commission has studied the principal tests that may be made on wire—*i. e.*, tensile, folding, winding, and torsion.

The Conventions require upon this subject only that the torsion test shall be made by means of suitable machines, and that the folding test shall be made by machinery bending the piece alternately in two opposite directions around a mandrel 5 millimeters in diameter.

The American Society reproduces those conclusions, requiring, however, that the diameter of the mandrel shall be equal to that of the wire.

The analogous test studied by our Commission is that of winding or wrapping. It requires that the diameter of the roller or spool shall vary according to the destined use of the thread, but requires that it shall be always a multiple of the diameter of the wire.

CHAPTER II.—TESTS ON WIRE ROPE.

Our Commission prescribes the rules to be followed in tests for tension and flexibility. The Conventions and the American Society require that a tensile and a shock test shall be made in the longitudinal direction without giving any further details on that subject. Our Commission expresses the hope that the study of tensile tests by shock may be continued, as well as the folding or winding tests, in order to furnish information as to flexibility.

The Conventions add that the folding test is of value only when continued for a given length of time.

CHAPTER III.—TESTS ON CHAINS.

Our Commission proposes submitting chains to a tensile test made at first under a moderate load, then carried to rupture, and it gives some instructions relating to the execution of that test. For the test under a moderate strain it proposes adopting a strain double that to be met with in actual service.

The American Society requires only that the chain shall be subjected to the service strain, and that the elastic and permanent elongation shall be measured as well as the change in the form of the links.

CHAPTER IV.—TESTS ON RIVETS.

As a special test on bars for rivets, the American Society presents only the hot flattening test.

Our Commission gives two principal tests; one to separate the two riveted bands or bars by means of a chisel with a given bevel driven by blows of a hammer, and the other to subject those bars to a sort of shearing test.

CHAPTER V.—TESTS ON PIPES AND TUBES.

The foreign resolutions give no special information in regard to the manufacture test to be made on pipes or tubes.

CHAPTER VI.—TESTS BY HYDRAULIC PRESSURE.

For tests of steam boilers the American Society recommends the adoption of the method used by the Hartford Inspection Company, which is already in general use in the United States.

Our Commission, without prescribing the methods of test required in France, points out the precautions to be observed and the verifications to be made in testing boilers.

For testing cylinders and pipes the American Society proposes the application of a pressure equal to the maximum working load. It requires, besides, that the dilation of pipes under that load shall be observed, as well as the permanent dilation, if any be produced, and to mention whether the pipe leaks.

In conclusion, our Commission recalls the fact that hydraulic pressure has been used recently to acquire desired data relating to the elastic deformation of metals; and it expresses the hope that those studies may be extended to plates.

PARIS, *March 15th, 1895.* L. BACLÉ.

OBITUARY.

GEORGE W. G. FERRIS, widely known as the inventor of the Ferris wheel, which was one of the leading features of the World's Fair at Chicago, died on November 22d, at Mercy Hospital, Pittsburg, Pa., from typhoid fever. He was born at Galesburg, Ill., but passed his early life on the Pacific coast, and was educated at San Francisco. In 1876 he entered the Rensselaer Polytechnic Institute, at Troy, N. Y., from which he graduated. Subsequently he entered the employ of the Louisville Bridge Company, at Louisville, Ky. Among other work which came under his direction in connection with this company was the structural work for the Louisville & Nashville Railroad bridge, at Henderson, Ky. After the completion of this work he organized the firm of G. W. G. Ferris & Co., in Pittsburg. In 1893 Mr. Ferris constructed the wheel which brought him a reputation throughout the world as an original engineering genius. Mr. Ferris had sold out his interest in the wheel some time before his death.

THE REFRACTIVE INDEX OF LUBRICATING OILS.

By G. W. Bissell, Ames, Iowa.

THE object of this paper is to present the results of some experiments made by the writer to discover the relation, if any, which exists between the index of refraction of an oil and some of its other properties, such as viscosity and specific gravity. The writer was led to make the experiments because the test for index of refraction is very readily, quickly, and accurately made.

The first series of tests was made by determining the viscosity, specific gravity, and refractive index of each of several mineral oils, all being the product of one refinery.

The results appear in the following table:

Name of Oil.	Refractive Index at 68° F.	Viscosity at 71° F.	Specific Gravity.
Water White Kerosene,	1.4434	10.6	——
Sewing Machine,	1.4695	14.2	——
Filtered Spindle,	1.4909	19.0	0.888
A. M. Spindle,	1.4942	19.6	.898
Arctic Engine,	1.4812	22.6	.873
Dynamo,	1.4825	22.9	.877
Arctic Machine,	1.4839	24.6	.874
Light Machine,	1.4885	27.6	.883
Red M. Engine,	1.4809	47.8	.877
Locomotive Engine,	1.4894	84.5	.970
Heavy Marine Engine,	1.4822	108.4	.894
Dark Marine Engine,	1.4869	120.0	.893
600 W. Cylinder,	1.4886	——	——

The viscosities are in seconds, and were obtained with a P. R. R. 100 cc. viscosity pipette.

The indices of refraction were obtained with an Abbé Refractometer, which actually measures the angle of total reflection, but is graduated to give refractive indices direct to four decimal places.

The second series of tests were made to determine the difference in refractive indices of mixtures of a clean machine-oil taken from the tank with varying proportions of the same oil after it had been run through bearings and was in need of filtering.

The following table shows the results:

Percentage of Clean Oil.	Percentage of Dirty Oil.	Refractive Index.	Temperature.
0	100	1.4816	69
10	90	1.4814	"
20	80	1.4815	"
30	70	1.4819	"
40	60	1.4804	"
50	50	1.4812	70
60	40	1.4814	71
70	30	1.4812	"
80	20	1.4811	"
90	10	1.4809	"
100	0	1.4816	69

The conclusions derivable from the above data are that there is no relation for the oils tested between the refractive index and either the viscosity for the specific gravity, and that dirty or cloudy oil has the same refractive index as unused oil of the same grade. This latter conclusion is in accordance with other investigations made in Germany, which showed that cloudiness of a liquid does not change its refractive power.

[Translation from article in *Stahl und Eisen*, January 1st, 1896.]

INVESTIGATIONS REGARDING THE INFLUENCE OF COLD UPON THE STRENGTH OF IRON AND STEEL.

By Professor M. Rudeloff.

A COMMISSION received from the Imperial Dock-yard at Wilhelmshafen by the Charlottenburg Experimental Station, presented the opportunity of making thorough investigations regarding the influence of cold as low as 80° C. upon the strength of various kinds of iron and steel. In view of the importance of this question, and in order to make the results of these investigations accessible to a wider circle of readers, a concise compilation of them is here given, while, regarding the details of the examination and the results obtained thereby, the reader is referred to the article on the same subject in *Mittheilungen aus den Königlichen technischen Versuchsanstalten*, 1895. Heft 5.

The investigations embraced tensile, bending, and riveting tests at the ordinary temperature of a room, as well as at 20° C., and at 80° C., three parallel experiments being always made.

In making the tests the following materials were employed:

1. Soft rivet iron (weld iron), round rods 25.5 millimeters in diameter.
2. Siemens-Martin ingot iron, angle of 100x100x14 millimeters.
3. Thomas steel from "Roth Erde," the same as No. 2.
4. Rolled weld iron, angle of 100x65x9 millimeters.
5. Spring steel, round rods 25 millimeters in diameter.
6. Cast steel, same as No. 5.
7. Wrought weld iron (tilted or hammered iron), same as No. 5.

For the tensile experiments small cylindrical rods were prepared from the round rods, and flat pieces from the angles. The dimensions adopted for all test-pieces were 80 millimeters cross-section and 100 millimeters testing length, so that all the materials could be directly placed in comparison with one another. The tests were executed with a 50-ton Pohlmeyer machine under a steadily increasing load with a working velocity as equal as possible.

For the riveting tests cylindrical pieces of a length equal to the diameter which, according to the original thickness of the material, amounted to from 8 to 10 millimeters, were used. Each piece received 10 blows of equal specific effect (*a*) which, for the materials Nos. 1 to 4 and No. 7 with a tensile strength of less than 50 kilogrammes per square millimeter, was adopted equal to 5 mkg. per ccm., and for the materials Nos. 5 and 6, with a tensile strength of over 50 kilogrammes per square millimeter, equal to 20 mkg. per ccm.

For the bending tests pieces 150 millimeters long were used. The test-pieces from the round rods Nos. 6 and 7 were not subjected to further manipulation, while for the purpose of facilitating bending the round rods Nos. 5 and 6 were turned down to 15 mm., and the test-pieces from the angles were cut 30 mm. in width and rounded off on the edges. Bending was induced in a screw press under a spindle 25 mm. in diameter to about 90°, and then continued by means of a steadily increasing load upon the leg ends.

For the experiments at —20° C., the chilling of the test-pieces was effected in a freezing mixture of ice and salt, and for the experiments at —80° C., in solid carbonic acid. In the tensile tests the pieces re-

TABLE I.

COMPARISON OF THE MEAN VALUES FROM TENSILE EXPERIMENTS.

MATERIALS.	Experimental Temperature °C.	Observation Values.				σ_S / σ_B	Proportional Figures.			
		Strains in Kilos Per Square Millimeter on the		Elongation by Rupture Measured in Per Cent. for			Strains in Kilos Per Square Millimeter on the		Elongation by Rupture Measured in Per Cent. for	
		Limit of Extensibility σS.	Limit of Rupture σB.	Each 30 Millimeters from Rupture.	90 Millimeters.		Limit of Extensibility σS.	Limit of Rupture σB.	Each 30 Millimeters from Rupture.	90 Millimeters.
1. Soft Rivet Iron (weld iron) marked "N,"	+ 18	28.7	39.7	30.2	27.7	0.72	100	100	100	100
	— 20	29.2	41.7	29.0	26.2	0.70	101.7	105.0	96.0	94.6
	— 80	30.4	42.7	26.6	23.8	0.71	105.9	107.5	88.1	85.9
2. Rolled Steel for ship construction (Siemens-Martin ingot iron) marked "Krupp,"	+ 18	24.0	40.4	39.5	32.8	0.59	100	100	100	100
	— 20	24.7	43.6	38.0	33.3	0.57	102.9	107.9	96.2	98.5
	— 80	29.7	45.2	—	(23.4)	0.66	123.8	111.9	—	(70.3)
3. Rolled Steel for ship construction (Thomas Steel from "Rothe Erde,") marked "Rothe Erde,"	+ 18	28.7	43.4	35.3	30.2	0.66	100	100	100	100
	— 20	30.4	45.5	33.8	29.5	0.67	105.9	104.8	95.8	97.7
	— 80	32.0	46.2	(31.9)	(26.2)	0.69	111.5	106.5	(90.4)	(86.8)
4. Rolled Weld Iron for building construction, marked "W,"	+ 18	30.9	40.2	(23.8)	21.3	0.77	100	100	100	100
	— 20	31.6	41.6	23.5	21.7	0.76	102.3	103.5	(98.7)	101.9
	— 80	31.9	43.2	—	20.2	0.74	103.2	107.5	—	94.8
5. Spring Steel, marked "F S,"	+ 18	38.7	77.2	17.7	16.0	0.50	100	100	100	100
	— 20	40.2	84.2	15.7	14.0	0.48	103.9	109.1	88.7	87.5
	— 80	44.4	84.4	12.8	10.9	0.53	114.7	109.3	(72.3)	68.1
6. Cast-Steel (crucible steel), marked "T S,"	+ 18	45.6	79.3	20.1	17.1	0.58	100	100	100	100
	— 20	45.7	81.6	20.0	16.8	0.56	100.2	102.9	99.5	98.2
	— 80	48.7	84.1	17.6	13.9	0.58	106.8	106.1	87.6	81.3
7. Wrought Weld Iron (tilted or hammered iron), marked "H,"	+ 18	27.3	37.1	26.3	21.3	0.74	100	100	100	100
	— 20	27.6	37.9	26.1	21.9	0.73	101.1	102.2	99.2	102.8
	— 80	32.1	40.3	(27.8)	23.3	0.80	117.6	108.6	105.7	109.4

mained in the cold baths during the entire experiment, while in the riveting and bending tests the pieces were taken from the baths for examination, but returned to them for 15 minutes to be chilled again, the pieces for the riveting tests being thus returned after each blow.

a. The mean values for the results of the tensile experiments are compiled in Table I, and graphically represented in Figs. 1 to 3. They admit of the following general deductions:

1. By cooling, the strain on the limit of extensibility as well as the breaking strain are increased.

2. With an equal fall in temperature the change in the limit of extensibility by reason of cooling to —20° C., is, generally speaking, slight as compared with that between —20° and —80° C., while the breaking strain is proportionally more influenced by slight cooling (to —20° C.) than by stronger cooling (to —80° C.).

3. Elongation by rupture (Fig. 3) decreases with increasing cold, and increases only with wrought weld iron (tilted or hammered iron). This influence is partially proportional to the fall in temperature and partially it first becomes especially pronounced between —20° and —80° C.

A comparison of the different varieties of iron shows that in the breaking experiment the Siemens-Martin ingot iron resisted least the influence of cooling to —80° C., the changes for the limit of extensibility amounting to + 23.8 %, for the breaking strain to + 11.9 %, and for the elongation to 90 mm. length to about —30 %*. Next to the Siemens-Martin ingot iron comes the spring steel (+ 14.7, + 9.3, and —32 %) †; then follow hammered iron (+ 17.6, + 8.6, and + 9.4); Thomas steel (+ 11.5, + 6.5, and —13.2); cast steel (+ 6.8, + 6.1, and —18.7 %); soft rivet iron (+ 5.9, + 7.5, and —14.1 %); and rolled weld iron (+ 3.2, + 7.5, and —5.2 %).

An interesting phenomenon in the rupturing experiments deserves special mention—namely, that, with increasing cold down to —80° C., all the varieties of iron and steel exhibited an increase in the flowing power (Fliessvermögen) under the load at the limit of extensibility, which, with a constant velocity of the rupturing machine, is given by the length of the extension *l* in the traced line, Fig. 4.

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* This value is doubtful, because of the three test-pieces tested at —80° C., two broke outside of the division, and the rupture of the third test-piece took place in the last division mark.

† These and the succeeding values are given in the same succession as for Siemens-Martin iron.

The separate values for the length of *l* were determined by the lines traced by the machine during the experiment, and are compiled in Table II. They show that the increase in the flowing power

TABLE II.

LENGTH OF THE HORIZONTAL PORTION *l* OF THE TRACED LINES ON THE LIMIT OF EXTENSIBILITY.

MATERIAL.	1		2		3		4		5		6		7	
Experimental Temperature. °C.	Rod No.	Length.	Rod No.	Length.	Rod No.	Length.	Rod No.	Length.	Rod No.	Length.	Rod No.	Length.	Rod No.	Length.
+ 18 . .	1	2.5	10	1.2	19	1.2	28	0	37	0	46	0.2	55	1.0
	4	2.0	13	—	22	1.4	31	0	40	0	49	0.1	58	1.5
	Mean	2.3	Mean	(1.2)	Mean	1.3	Mean	0	Mean	0	Mean	0.2	Mean	1.3
— 20 . .	2	2.8	11	2.2	20	3.2	29	1.0	38	0.3	47	0.2	56	1.0
	5	3.5	14	2.8	23	4.0	32	2.5	41	0.2	50	0.9	59	1.0
	8	3.1	17	1.8	26	—	35	2.0	44	0.2	53	1.0	62	1.5
	Mean	3.1	Mean	2.3	Mean	3.6	Mean	1.8	Mean	0.2	Mean	0.7	Mean	1.2
— 80 . .	3	5.2	12	3.0	21	5.0	30	—	39	0.2	48	1.0	57	5.0
	6	4.2	15	3.2	24	5.2	33	3.6	42	1.0	51	1.2	60	(4.0)
	9	5.0	18	—	27	5.3	36	2.0	45	0	54	1.0	63	(9.0)
	Mean	4.8	Mean	(3.1)	Mean	5.2	Mean	2.8	Mean	0.4	Mean	1.1	Mean	6.0

(Fliessvermögen) under the load at the limit of extensibility was a general one, and showed itself even in materials Nos. 4 and 5—rolled weld iron and spring steel—which did not possess it at the ordinary temperature of a room.

This observation enters into close connection with that made by Charpy, according to which the flowing power (Fliessvermögen), while existing distinctly at the ordinary temperature of a room, gradually disappears with increased heating.

b. In view of the method used in making the experiments, *the results of the riveting tests* can be best reviewed by considering the decrease in height the test-pieces suffered after receiving blows of equal specific effect at the three different degrees of temperature. This comparison may be carried out for blows of an effect of 10, 20, 30, and 40 mkg. per ccm. For this purpose lines were constructed from the separate observation values, the repetition of which, for the sake of brevity, is here omitted by laying down the effects of the blows as abscisses and the decreases in height belonging thereto as ordinates, and from these lines the decreases in height for the effects of the four blows mentioned above were taken. The values obtained thereby are compiled in Table III, together with figures giving the prpportion of decrease in height at lower degrees of temperature to that at the ordinary temperature of a room.

TABLE III.

INFLUENCE OF COOLING UPON THE DECREASE IN HEIGHT OF THE RIVETING TEST-PIECES BY BLOWS OF EQUAL SPECIFIC EFFECT.

MATERIALS.	Testing Temperature, °C.	Decrease in Height by the Effect of the Blows, taken from the Constructed Lines; in mkg. per ccm.				Proportion of the Decrease in Height at Lower Degrees of Temperature by the Effect of Blows to that at the Ordinary Temperature of a Room, the Latter Effect Placed = 100 in mkg. per ccm.				
		10	20	30	40	10	20	30	40	Mean.
1. Soft Rivet Iron (weld iron), mark'd "N,"	+ 18	13.2	21.5	28.1	33.2	100	100	100	100	100
	— 20	12.4	20.4	26.2	31.0	94	95	93	93	94
	— 80	9.5	16.6	22.0	27.0	72	77	78	81	77
2. Rolled Steel for ship constructi'n (Siemens-Martin ingot iron), ...	+ 18	12.8	21.5	28.3	33.3	100	100	100	100	100
	— 20	12.8	21.5	27.0	32.0	100	100	95	96	98
	— 80	10.0	17.0	22.5	26.7	78	79	79	80	79
3. Same as above, Thomas Steel from "Rothe Erde," . .	+ 18	13.5	21.4	27.5	32.4	100	100	100	100	100
	— 20	12.0	20.0	25.8	30.7	89	94	94	95	93
	— 80	10.5	17.9	23.1	27.8	78	84	84	86	83
4. Rolled Weld Iron for building construction, . . .	+ 18	15.3	24.2	32.3	—	100	100	100	100	100
	— 20	13.0	21.4	27.5	—	85	88	85	—	(86)
	— 80	12.2	21.0	27.6	—	80	87	85	—	(84)
5. Spring Steel,	+ 18	7.8	14.7	20.2	25.0	100	100	100	100	100
	— 20	7.0	13.5	18.8	23.5	90	92	93	94	92
	— 80	7.1	12.0	17.2	22.0	78	82	85	88	83
6. Cast Steel, .	+ 18	8.3	15.5	21.5	26.5	100	100	100	100	100
	— 20	8.3	15.5	21.0	26.0	100	100	98	98	99
	— 80	6.0	12.0	17.8	23.3	72	77	83	88	80
7. Wrought Weld Iron (tilted or hammered iron), . . .	+ 18	13.8	22.8	29.7	35.1	100	100	100	100	100
	— 20	13.5	21.6	27.8	--	98	95	94	—	(96)
	— 80	12.2	19.5	24.5	28.9	88	86	83	82	85

From the mean values for these proportional figures it follows:

1. That the more the materials were cooled the less their shape was altered under blows of equal effect. Hence, by the influence of cold the capacity of the matertal for having its shape altered by riveting had suffered in a like manner as its power of extension in the rupturing experiment, though the influence upon the riveting capacity did not run entirely parallel with that upon the extensibility.

2. The magnitude in the loss of riveting power amounts at —20° C. up to 8 per cent., and at —80° C. up to 23 per cent.

3. By arranging the materials examined in accordance with the increasing influence of cold the following series is obtained: Hammered iron, rolled weld iron, Thomas steel, spring steel, cast steel, Siemens-Martin iron, and soft riveting iron.

c. The bending tests judged by the magnitude of the bend $Bg = 50 \frac{\delta}{\sigma}$, if δ equals the thickness or diameter of the test-piece and σ the diameter of the curve, and by the bending angle w, show:

1. That, generally speaking, cooling to —20° C. exerted but little influence upon the flexibility of the varieties of iron examined.

2. The flexibility of the test-pieces of soft rivet iron and rolled weld iron was not seriously affected by cooling to —80° C., but that of all the other materials suffered by reason of the lower temperature.

3. The greatest effect was produced on cast steel and spring steel; then follow Siemens-Martin ingot iron and Thomas steel with about the same effect, while the three varieties of weld iron showed the greatest resisting power. It must, however, be noticed that, notwithstanding the perceptible influence of cold, the Siemens-Martin iron and Thomas steel showed throughout greater flexibility at —80° C. than the rolled and wrought weld irons, and in this respect were not surpassed by the soft rivet iron (weld iron).

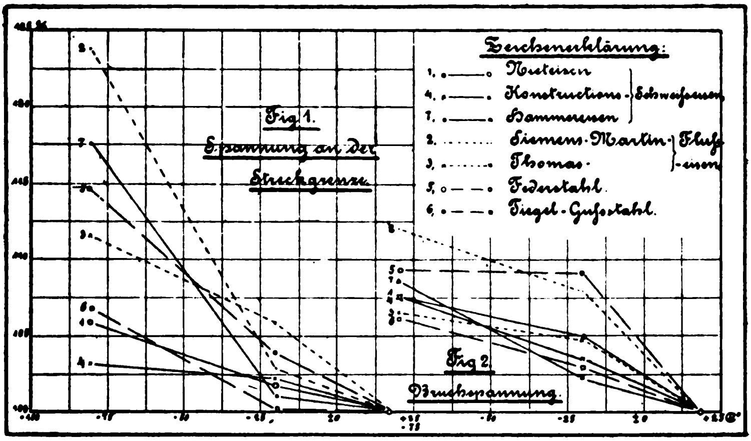


Fig. 1.—Strain on the limit of extensibility.
Fig. 2.—Breaking strain.

Explanation of the Figures.

1. o———o. Rivet iron.
4. x———x. Structural weld iron.
7. x———x. Hammered iron.
2. . . . Siemens-Martin, } ingot iron
3. x . . . x. Thomas, } ingot iron
5. o— —o. Spring steel.
6. o— —o. Crucible cast-steel.

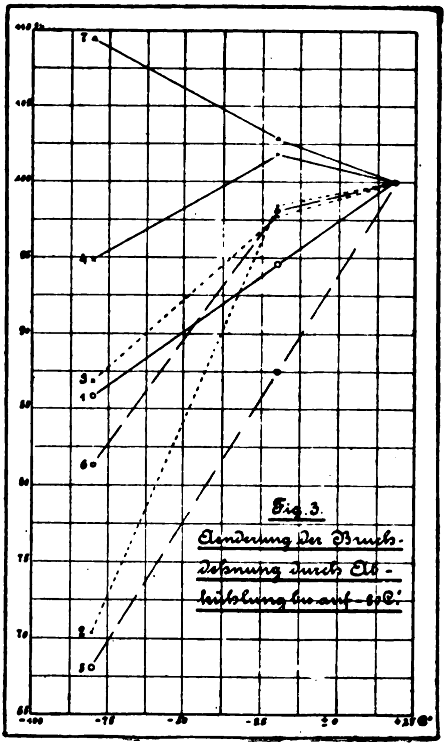
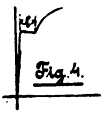


Fig. 3.—Alteration in the elongation by fracture by cooling to —80° C.



EFFECT OF AN ADDITION OF GYPSUM TO PORTLAND CEMENT.

F. SCHOTT has observed by the prisms in the Bauschinger apparatus the changes in volume of cements of different composition, and has compiled the results in the following table:

Hardening Time.	Extension per 100 Meters Length in Millimeters.							
	$2CaOSiO_2$.	100 Parts $2CaOSiO_2$ + 63 Parts Gypsum.	Kaolin Cement containing 12.53% Al_2O_3.	100 Parts Kaolin Cement + 63 Parts Gypsum.	Iron Cement containing 12.19% Fe_2O_3.	100 Parts Iron Cement + 38.7 Parts Gypsum.	$2CaOAl_2O_2$.	1 Part $2CaOAl_2O_2$ + 1 Part Gypsum.
7 days.	0	0	+ 30	Swells very much.	+10	+ 50	+190	+ 285
28 "	0	0	+120		+35	+210	+605	+ 785
90 "	— 5	0	+310		+35	+300	+705	+1240
180 "	— 7	—15	+540		+20	+385	+775	Swells very much.
270 "	—15	—20	+575		+15	+495	+880	
360 "	—20	—30	+600		+15	+690	+920	
1¼ years.	—40	—45	+610		+15	+886	+940	
1½ "	—60	—50	+630		—	—	—	

The greatest constancy in volume is exhibited by the cement containing only lime and silica, 100 parts of such cement mixed with 63 parts gypsum showing no extension, even after 1½ years, but a slight reduction in volume. The cement prepared from kaolin which, besides silica, contains 12.53 per cent. alumina, shows an essentially different behavior. Even without the addition of gypsum it exhibits strong extension, and mixed with 63 parts gypsum ($CaSO_4 + 2aq$) to 100 parts of cement it swells very much. The gypsum was measured to correspond with the 12.53 per cent. alumina, present by reason of the double combination of gypsum with calcium aluminate, $Al_2O_3,3CaO + CaSO_4$, assumed by Michaelis. While iron cement by itself behaves like good Portland cement, when mixed with gypsum it shows progressive strong extension, so that chemical actions similar to those between gypsum and calcium aluminate also take place between gypsum and calcium ferrate. The combination, $2CaOAl_2O_3$, shows from the start strong extension, which is still further increased by an addition of gypsum. To obtain a clear insight into the chemical processes upon which this phenomenon is based, the combination, $2CaOAl_2O_3$, was scorified and mixtures of it with 1, 2, and 3 equivalents of hydrous gypsum prepared. These mixtures were reduced to fine powder in an agate dish and 2 grammes of each brought into test-tubes previously weighed. Fifty c. cm. of water were then poured over the contents of the test-tubes to test their capacity for absorbing water. While 100 parts of the combination, Al_2O_32CaO, by hardening in water and forming the hydrate with 5 equivalents of water, absorb 41.92 parts of water, 100 parts of Al_2O_32CaO in the presence of 2 equivalents of gypsum and the formation of the double combination with 18 equivalents of water reabsorb 118.38 parts of water, which explains the swelling.

STRENGTH OF CEMENT MORTARS AFTER HARDENING FOR SOME TIME IN THE OPEN AIR.

AS a contribution to the hardening of cement mortar in the air by the action of carbonic acid, R. Dyckerhoff communicates the following results of his observations on mortar with 1 to 10 parts sand, made from cement which by the normal test showed a tensile strength of 23.6 kilogrammes and a compressive strength of 232 kilogrammes. The mortars were allowed to harden for one week in water, and were then exposed to the weather in the open air:

Mortar Mixture in Parts by Weight.	Residue in per cent.		Tensile Strength in Kilos for 1 Square Centimeter.								
	5000 Mesh Sieve.	900 Mesh Sieve.	1 Week.	4 Weeks.	13 Weeks.	26 Weeks.	1 Year.	2 Years.	3 Years.	4 Years.	5 Years.
1 cement : 1 sand,	22.3	3.0	25.5	27.4	41.4	41.9	45.5	62.3	61.5	63.3	69.1
1 " : 2 "	. .	. .	22.2	26.5	38.3	39.1	42.4	55.2	58.1	59.3	6.43
1 " : 3 "	. .	. .	18.6	23.4	34.5	35.4	36.6	50.9	46.2	56.3	5.79
1 " : 6 " + ½ calcium hydrate,	. .	. .	10.9	18.1	22.8	28.0	32.2	42.3	41.3	43.5	51.0
1 " : 8 " + ¾ " "	. .	. .	7.1	13.7	19.7	24.8	28.5	37.9	35.0	39.2	44.5
1 " : 10 " + 1 " "	. .	. .	5.4	11.6	17.0	21.3	23.4	34.4	31.2	36.0	36.9

The lime used for the experiments was hydraulic lime from Beckum, and the sand, Rhine sand sifted through a 5-millimetre mesh sieve.—*Chemisch-technisches Repertorium.*

Bicycle Frame Tests—Luminum versus Steel Tube.

SUMMARY OF TESTS.

SERIES A. STATIC LOAD ON CRANK HANGER.

Luminum Frames, average crippling strength, . . . 2,775 pounds
" " " ultimate " . . . 3,623 "
Stearns " " crippling " . . . 2,925 "
" " " ultimate " . . . 4,172 "
" " show 5½ per cent. higher crippling strength.
" " " 15 " " ultimate "

SERIES B. STATIC LOAD ON SEAT POST

Luminum Frames, average crippling strength, . . . 4,219 pounds
" " " ultimate " . . . 4,344 "
Stearns " " crippling " . . . 4,275 "
" " " ultimate " . . . 5,438 "
" " show 1½ per cent. higher crippling strength.
" " " 25 " " ultimate "

SERIES C. STATIC LOAD IN LINE OF SPROCKETS.

Luminum Frames, average ultimate strength, . . . 1,750 pounds
Stearns " " " " . . . 2,600 "
" " show 48½ per cent. higher ultimate strength.

SERIES D. STATIC LOAD ON PEDAL ON ONE SIDE.

Luminum Frames, average crippling strength, . . . 300 pounds
" " " ultimate " . . . 1,268 "
Stearns " " crippling " . . . 845 "
" " " ultimate " . . . 1,250 "
" " show 181½ per cent. higher crippling strength.
Luminum " " 1½ " " ultimate "

SERIES E. IMPACT ON SEAT POST.

Luminum Frames, average crippling strength, . 2,575 inch-pounds
" " " ultimate " . 4,055 "
Stearns " " crippling " 13,300 "
" " " ultimate " 15,900 "
" " show 416 per cent. higher crippling strength.
" " " 202 " " ultimate "

SERIES F. IMPACT ON CRANK HANGER.

Luminum Frames, average crippling strength, . 6,573 inch-pounds
" " " ultimate " . 6,820 "
Stearns " " crippling " . 8,678 "
" " " ultimate " . 9,857 "
" " show 32 per cent. higher crippling strength.
" " " 44½ " " ultimate "

SERIES G. HORIZONTAL IMPACT ON FRONT FORK.

Luminum Frames, average crippling strength, . 1,273 inch-pounds
" " " ultimate " . 1,575 "
Stearns " " crippling " . 3,544 "
" " " ultimate " . 4,463 "
" " show 178 per cent. higher crippling strength.
" " " 183 " " ultimate "

NOTES AND COMMENTS.

LITERATURE.

Notes on Mechanical Laboratory Practice by C. H. Benjamin, Professor of Mechanical Engineering, Case School of Applied Science, Cleveland, Ohio.

This work is an embodiment of the essentials of the means, material, and machine used in testing materials directly connected with mechanical engineering. Professor Benjamin has introduced a routine or system for the laboratory, which in itself is highly commendable; for, the quicker a student is taught systematic practice, the more readily will he fall into line, when no longer under a Professor, but rubbing against the unsympathetic competition of the world. While designed for the use of students, it is also invaluable for the professional man, as a book of reference. The book is well printed on good paper, and the various appliances mentioned in contents below clearly illustrated.

CONTENTS.

Chapter I.—The Strength of Materials.—The testing machine. Extensometers and other measuring instruments. Forms of specimens. Routine for various tests and forms for reports.

Chapter II.—Dynamometers.—Absorption and transmitting dynamometers. Alden dynamometer. Webber dynamometer. Belt-testing machine. Calibration of dynamometers. Directions for use and forms for reports.

Chapter III.—Measurement of Heat and Steam.—Thermometers, pyrometers, draft, and steam gauges. Calibration of apparatus. Barrel calorimeter. Throttling calorimeter. Separating calorimeter. Barrus calorimeter. Forms for reports.

Chapter IV.—The Testing of Steam Boilers.—Equivalent evaporation. Table of factors. Standard method of making a boiler test. Simple forms for ordinary trials.

Chapter V.—Indicators and Planimeters.—Directions for the care of indicators and their calibration. Reducing motions. Directions for the use of indicators. Theory of the polar planimeter and directions for its use. Indicator diagrams.

Chapter VI.—Testing Steam Engines.—Instruments. Test of surface condenser. Directions for making an engine test and forms for reports. Standard method for duty trials of pumping engines. Testing small pumps. Tables.

DIGEST OF PHYSICAL TESTS.

[For the convenience of the readers of the DIGEST OF PHYSICAL TESTS we have arranged below a list of treatises and notes that have appeared in many of the leading mechanical newspapers and magazines during the year 1896. The titles and dates of the papers containing the articles, and names of the writers, are given when they could be obtained. Although some of the above-referred-to articles are very short, and may prove of little value, still the list embraces contributions large and small, and will doubtless prove of advantage for ready reference.—EDITOR.]

APPENDIX A.

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Transverse Strength of Timber,	"	"	"	"
Sand Test, Compression,	"	"	"	"
Sand Test, Tension,	"	"	"	"
Neat Cement, Compression,	"	"	"	"
Neat Cement, Tension,	"	"	"	"
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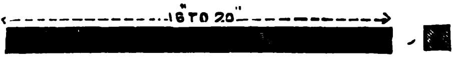
Form of Specimen for Tensile Tests of Wrought and Cast Iron, Steel and Alloys.

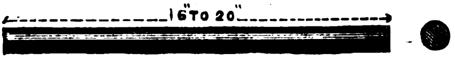
The specimens to be tested must not be over three inches wide, and of the shapes illustrated below, and up to 4 ft. long. The sectional area must not be of such proportions as to require a greater strain than 200,000 pounds to break them.

No. 1.



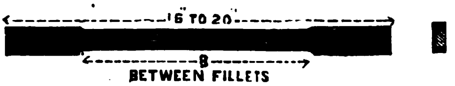
Square or flat bar, as rolled.

No. 2.



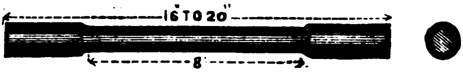
Round bar, as rolled.

No. 3.



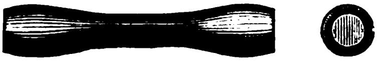
U. S. Government and American Society Civil Engineers' standard shape for specimen cut from plate. Ends must not be over three inches wide.

No. 4.



American Society Civil Engineers' standard shape for square or round, turned down in middle.

No. 5.



Standard shape for cast iron. Reduced section, 1 inch area.

Form of Specimen for Tensile Tests of Chain, Rope, Etc.

No. 6. Chain.

Any length from 18 in. to 4 ft., measuring inside of shackles. The outside measurement of shackles must be 3 in. x 4 in. or less, viz.: so as to go through a hole 3 in. x 4 in. large.

No. 7. Wire Rope.

Any length from 18 in. to 4 ft., measuring inside of loops. The outside measurement of end loops must be 3 in x 4 in., viz.: so as to go through a hole 3 in. x 4 in. large.

No. 8. Hemp Rope.

Any length from 18 in. to 4 ft., measuring inside of loops. The outside measurement of end loops must be 3 in. x 4 in. or less, viz.: so as to go through a hole 3 in. x 4 in. large.

Tensile Tests can be made up to four feet in length, and **Transverse Tests** up to five feet. Transverse specimens of cast iron are made: 1 in. square, 14 ins. long, for 12-in. tests; 1 in. square, 26 ins. long, for 24 in. tests; 1 in. square (or 1 x 2 ins.), 52 ins. long, for 48-in. tests; 1 in. square (or 1 x 2 ins.), 58 ins. long, for 54-in. tests. Greater lengths can be tested, but for these special quotations must be made.

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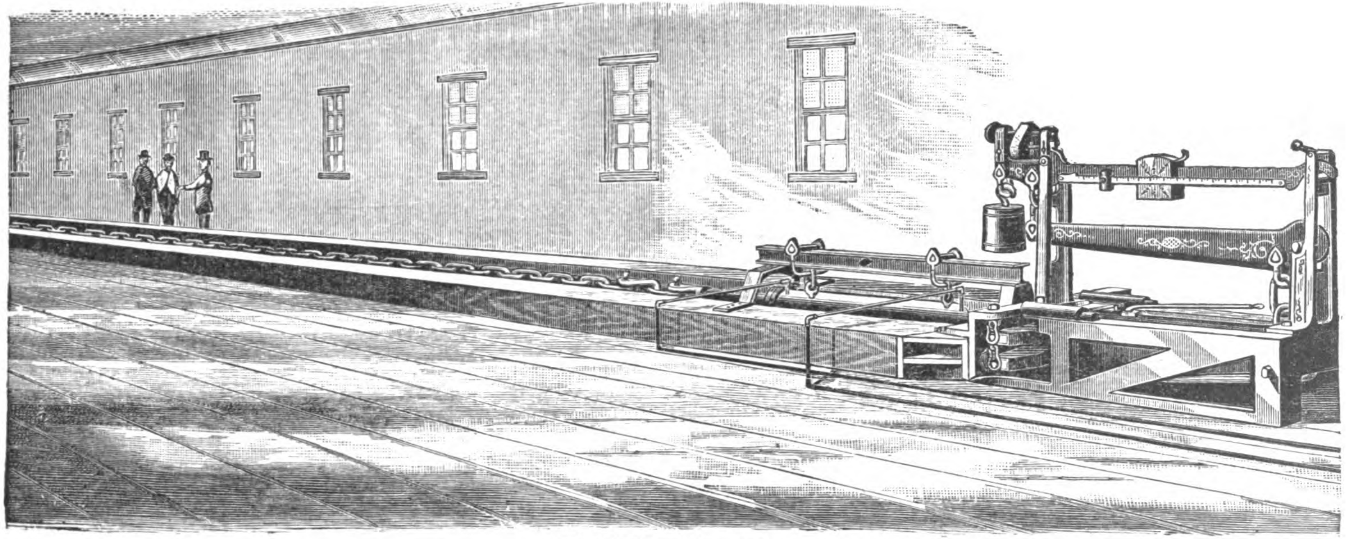

PLATE No. 22.

These Testing Machines are made in capacities ranging from 10,000 lbs. to 1,000,000 lbs., and are adjusted to the standard of all nations. They are constructed under plans approved by the "BRITISH LLOYDS," and certificates furnished from this Association when desired. These certificates are recognized all over the world, and tests made upon machines operated under same are accepted everywhere. In the engraving the Hydraulic Pump is not shown, but a high grade efficient Hydraulic Pump of variable stroke is furnished with the machine.

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Vol. II. APRIL, 1897. No. 2.

The Digest
OF
Physical Tests
AND
Laboratory Practice.

A résumé of Practical Tests made in the Laboratories of the World.

JOSEPH W. BRAMWELL, EDITOR.

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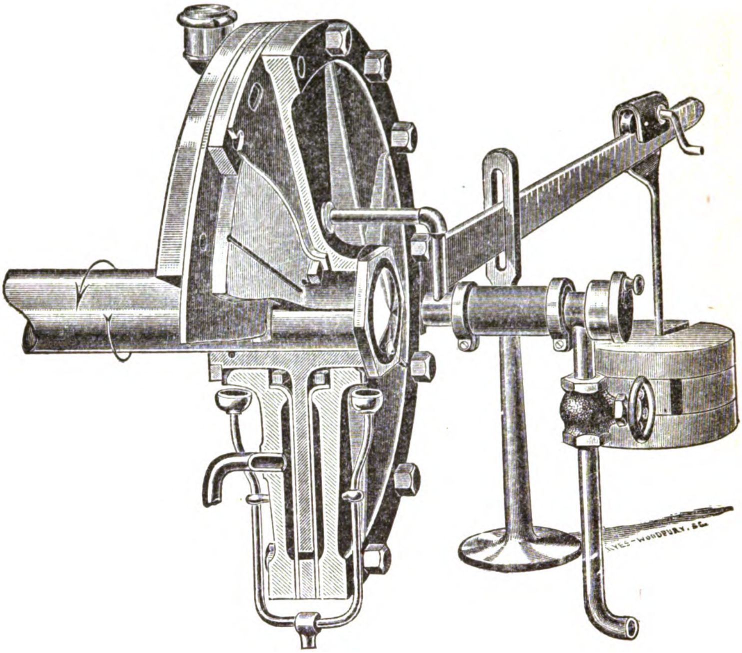

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DIMENSIONS.

Extreme Height,	about 3 feet.
Extreme Length,	" 7 feet.
Extreme Width,	" 2 feet.
Weight,	" 250 lbs.
Shipping Weight,	" 325 lbs.

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This apparatus has 28 inch disc; by increasing the number of discs, keeping the **same size, the Dynamometer** will absorb over 100 horse-power at 100 revolutions per minute.

This Dynamometer, the invention of Prof. G. I. ALDEN, of Worcester, Mass., takes the place of all forms of the Prony Brake; is self-regulating perfectly steady, and is self-contained. The power is absorbed by a disc rotating with shaft of machine between copper plates held in an outer casing. The pressure against these copper plates is produced by water regulated by a valve of peculiar construction, which operates automatically. The outer casing has a beam carrying a poise to balance the friction between revolving disc and copper plates. The disc runs in a bath of oil and is kept cool by a constant stream of water flowing through. The friction produced is the friction of oil.

It is indispensable in making accurate tests of motors of all kinds, steam engines, water wheels, or steam turbines. Its neatness and ease of management make it particularly desirable in every testing laboratory. **It has been thoroughly tested for three years,** and is perfect in its working.

This Dynamometer is suitable for measuring the power of Machines, Engines, Motors, Shafting, etc., and every Factory, Machine Shop, and Institute of Learning should have one.

Digest of Physical Tests.

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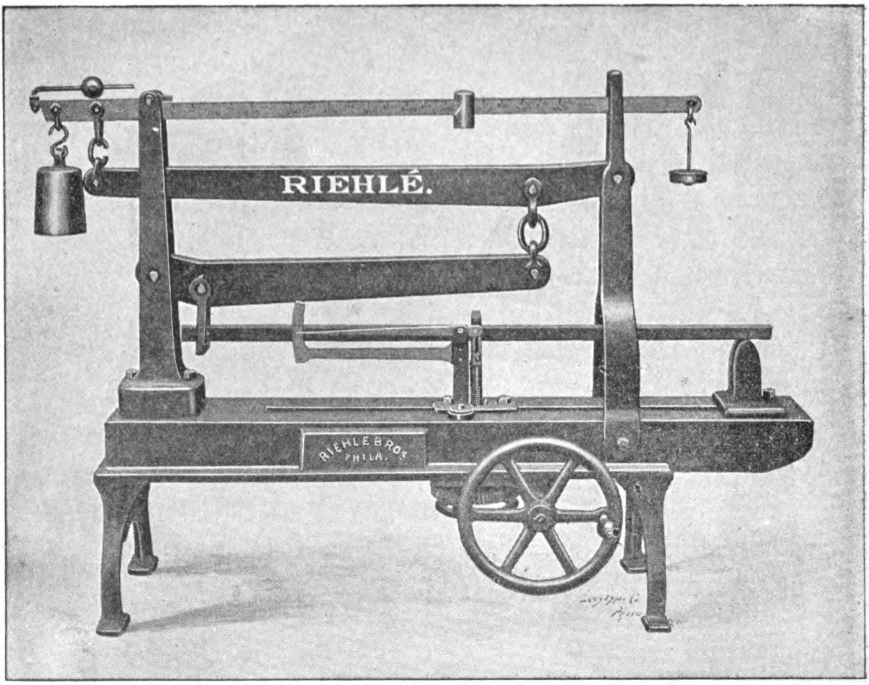

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Yours very truly
Philip Hichborn, Chief Constructor
U. S. Navy

Digest of Physical Tests.

A RÉSUMÉ OF PRACTICAL TESTS MADE IN THE
LABORATORIES OF THE WORLD.

Vol. II. **APRIL, 1897.** **No. 2.**

PHILIP HICHBORN, U. S. N., CHIEF CONSTRUCTOR, U. S. NAVY.

By Frederick A. Riehlé.

WE take pleasure in presenting to our readers an engraving of Chief Constructor Philip Hichborn, of the United States Navy. He is a descendant of one of the most distinguished and revered personages identified with the early struggles of our country, and one who contributed to the success of the war for independence. We refer to Paul Revere. At the age of twenty-one Mr. Hichborn was graduated from the Boston High School, and received, supplementary to a five years' tuition as shipwright's apprentice at the Boston Navy Yard, a course of special instruction in the construction, calculation, and design of ships. This was by special direction of the United States Navy Department.

In the year 1860 he sailed from Boston for California. During this voyage, which was an exceedingly tempestuous one and of 150 days' duration, he gained much valuable information concerning the requirements of nautical life, which he claims to have proved of the greatest value to him ever since. He served a term of two years in the United States Navy Yard, Mare Island, California. At the commencement of this term he entered in an humble position in the Construction Department. By assiduous labor and intelligent energy he was rapidly promoted to the position of Master Shipwright. This was at the early age of twenty-three, a very early age to assume such an important position.

Mr. Hichborn, at this age, was often called upon to take the entire control of the Construction Department in the absence of the Naval Constructor.

He entered the Navy as an Assistant Naval Constructor in the year 1869, and six years later passed an exhaustive examination and was commissioned full Naval Constructor. He has visited the principal European dock yards and made reports to the Government, and has devoted all his time to matters pertaining to the construction of naval vessels. Although special advantages have been enjoyed by the Chief Constructor since his early advent into his professional career up to the present time, yet no one would have received and merited the distinguished position which he now occupies unless one who was endowed with special intuition and great mechanical ability, coupled with what some persons term genius, but is truthfully the result of assiduous and unremitting labor.

In many positions the duties become less arduous as positions are advanced in grades and importance, but we know that in this branch of the Navy Department the duties are more exacting and arduous as Chief Constructor than in any of the under positions. "The recent order of the Department regarding the Bureau's work raises him to the dignity comparable to that of Chief of Naval Construction in England, and added responsibility to which he responds without the slightest tax upon his resourcefulness." He has resided in many cities during his different terms of service, and made extensive acquaintance with the leading people of the several places of his temporary sojournment. It is considered unnecessary and fulsome, and not called for in an article of this kind to make any personal mention of the genial disposition and distinguished courtesy of the subject of this brief sketch, but the writer cannot refrain from adding his testimonies to the friendly receptions given him whenever he was granted the pleasure of an interview.

TESTS OF A WROUGHT-IRON CAR AXLE.

By W. F. M. Goss.

WHILE much has been written concerning the variety and intensity of the stresses which service conditions impose upon car axles, there have been presented but few descriptions of the behavior of such axles when under stresses that are simple and definite in character. Interesting material of the latter class is supplied by a recent test of a 60,000-pound axle made in the Engineering Laboratory of Purdue University.

The axle tested was supplied by the Bass Foundry and Machine Works of Fort Wayne. It is said to have been made of No. 1 wrought railroad scrap, and to have been selected at random from a lot of 100 which were being shipped to a railroad company, and with it there was delivered to the laboratory a small test-specimen which had been drawn down from the crop end of the axle. As prepared for the tests the axle carried two 33″ cast wheels, and it was tested under transverse stresses, while the small specimen was subjected to tensional tests. The work was executed by Mr. J. H. Klepinger, who perfected details in the general plan and was painstaking in the manipulation of the apparatus.

The tests were made on a 300,000-pound Riehlé testing machine, a general view of which, with the axle in place for testing, is shown by Fig. 1. Fig. 2 gives the dimensions of the axle and the details of the arrangements for applying loads. The axle was supported by cast-iron blocks AA, 4 inches in breadth, shaped to the form of a bearing and extending from the centre to the outer end of the journal. The actual points of support were located in the centre of these blocks. Load was applied to the wheel treads through steel rollers BB, which at the beginning of the test were located 4 feet 10 inches apart; that is, at a point corresponding to a position three-fourths of an inch outside of the inner or "gauge face" of the rail upon which it may be supposed the wheels were set to run. In this manner stresses were imposed upon the axle which were in every way similar to those which might have been imposed by a car, if the axle had been in service, but to give greater facility in testing the usual

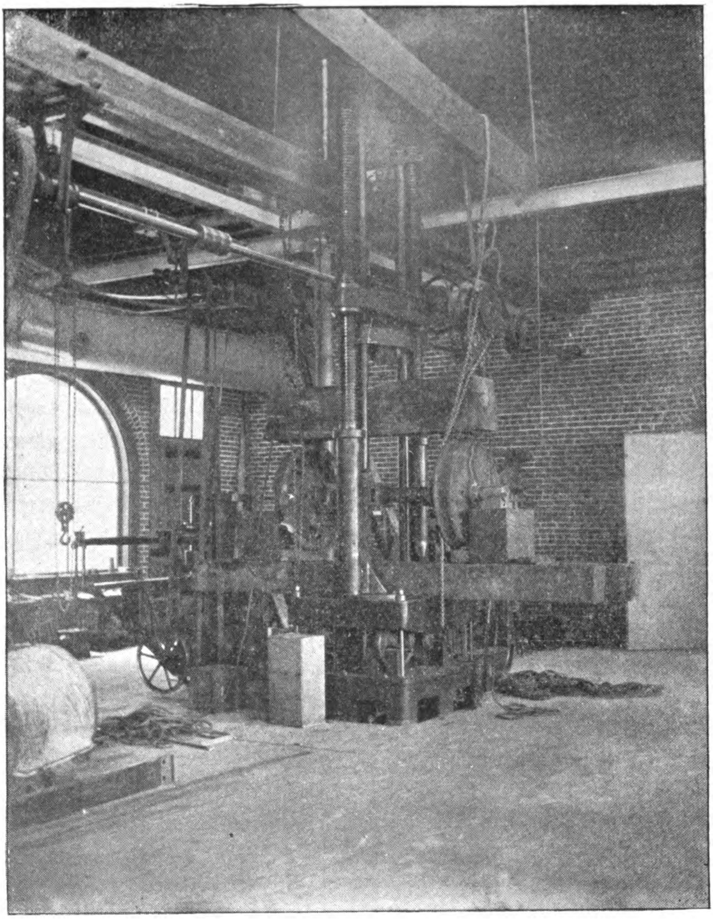

FIG. I.

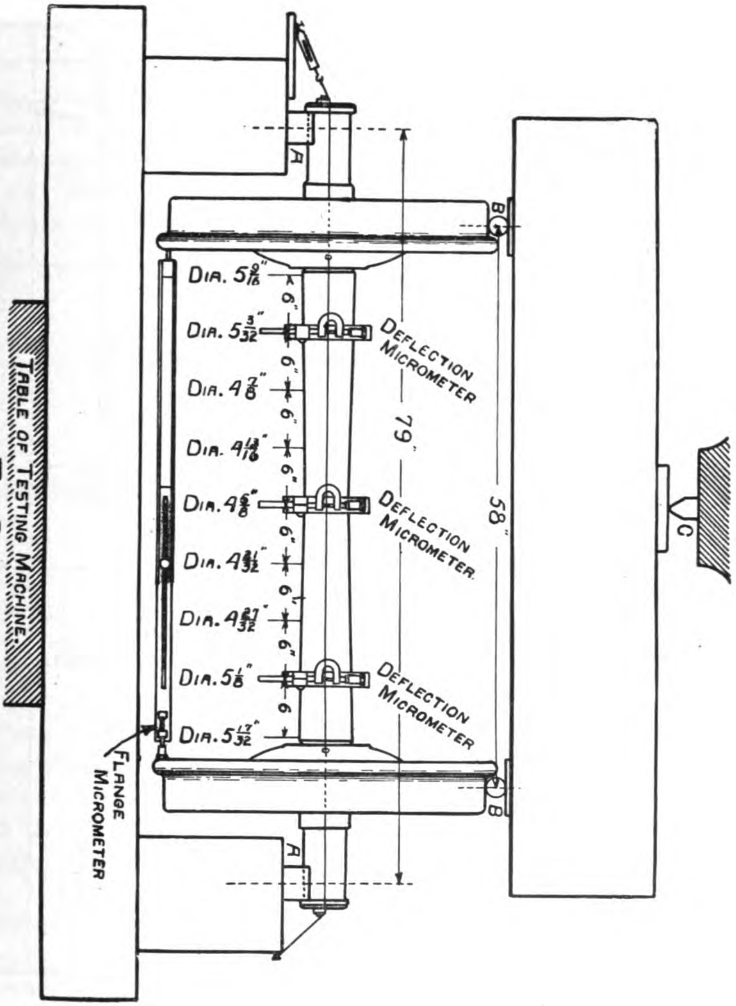
Table of Testing Machine.
A
B
Dia. 5 9/16"
6"
Dia. 5 3/32"
6"
Dia. 4 7/8"
6"
Dia. 4 13/16"
6"
Dia. 4 5/8"
6"
Dia. 4 21/32"
6"
Dia. 4 27/32"
6"
Dia. 5 1/8"
6
Dia. 5 17/32"
Deflection Micrometer
Deflection Micrometer
Deflection Micrometer
79"
58"
C
B
A
Flange Micrometer

Fig. 2

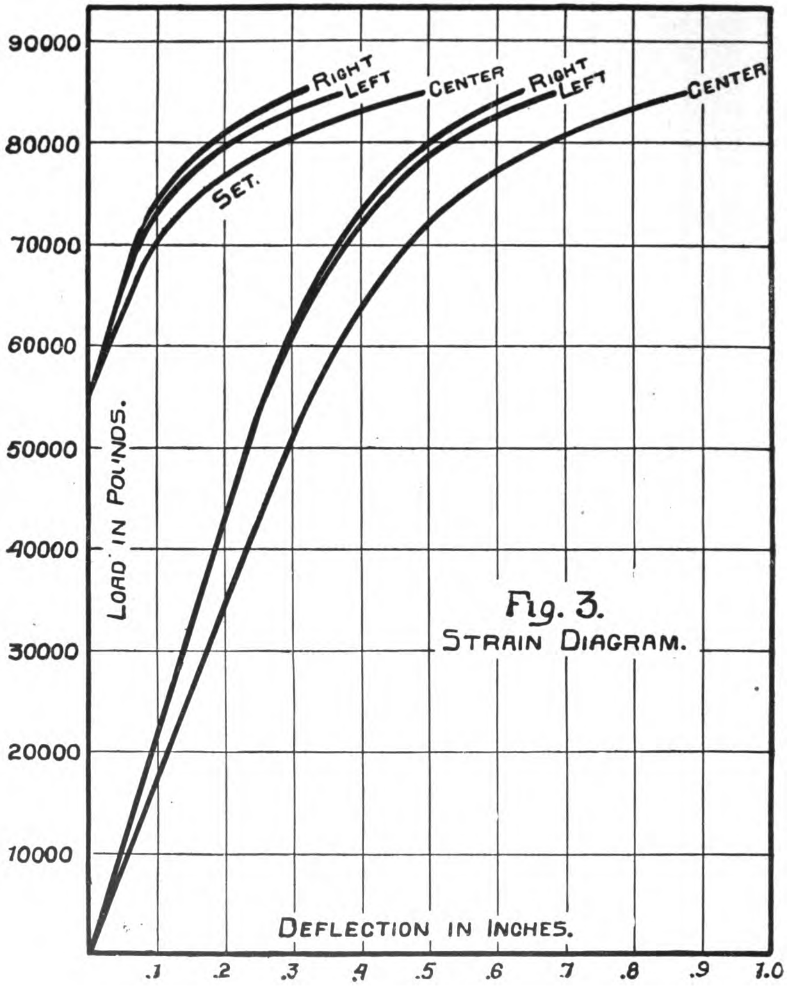

Fig. 3.
Strain Diagram.

order was reversed, the rails being assumed to be above the axle and the car below.

Fig. 2 shows also the means employed in determining the deflections corresponding to different loads. At each end of the axle there was attached a light arm bb, extending at right angles both to the axle and to the plane of the stresses to which it was subjected. Over these was stretched a fine wire parallel to the axis of the axle. The wire passed through the web of the wheels, in holes which were drilled for the purpose and made sufficiently large to give ample clearance. The whole length of the wire between the arms bb was at all times perfectly free, and the arrangement was such that although the axle might be bent by loads applied to it, the wire would remain straight. Three micrometers attached to blocks clamped about the axle, served to locate the latter with reference to the wire, and thus to determine the deflection. A fourth micrometer was used to measure distances between the wheel flanges in a line parallel with the axle and 16½″ distant from its centre.

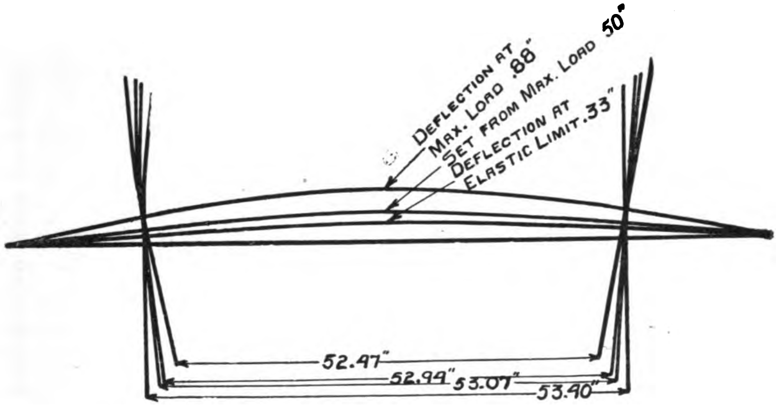
DEFLECTION AT MAX. LOAD .88"
SET FROM MAX. LOAD .50"
DEFLECTION AT ELASTIC LIMIT .33"
52.47"
52.99"
53.07"
53.40"

Fig. 4.

Loads were applied at C in 5,000-pound increments, and all micrometers were read before each change of load. In this way a maximum load of 85,000 pounds was applied under which the axle showed unmistakable signs of failure, the elastic limit having been reached with a load of 55,000 pounds. The results are presented graphically by Fig. 3, in which the curve marked "centre" represents the deflections of the centre of the axle as determined by the middle micrometer, Fig. 2; the curves marked "right" and "left" represent corresponding deflections for points 18″ either side of the centre. Deflections of the axle involved changes in the gauge of the wheels as measured above or below the axle, the extent of which is indicated by Fig. 4.

The actual readings of all micrometers are given in the tabulated statement below.

Load.	Micrometer Readings at Different Loads.								Total Deflection.			
	Centre.	Difference of Centre.	Left.	Difference of Left.	Right.	Difference of Right.	Flange.	Difference of Flange.	Centre.	Left.	Right.	Flange.
0	.084		.250	0	.176		.145		0	0	0	0
5,000	.111	.027	.275	.025	.200	.024	.175	.030	.027	.025	.024	.030
10,000	.138	.027	.297	.022	.220	.020	.199	.024	.054	.047	.044	.054
15,000	.151	.013	.310	.013	.233	.013	.228	.029	.067	.060	.057	.083
20,000	.190	.039	.339	.029	.264	.031	.265	.037	.106	.089	.088	.120
25,000	.226	.036	.365	.026	.288	.024	.290	.025	.142	.115	.112	.145
30,000	.255	.029	.388	.023	.311	.023	.315	.025	.171	.138	.135	.170
35,000	.284	.029	.412	.024	.334	.023	.369	.054	.200	.162	.158	.224
40,000	.315	.031	.435	.023	.357	.023	.370	.001	.231	.185	.181	.225
45,000	.347	.032	.455	.020	.380	.023	.401	.031	.263	.205	.204	.256
50,000	.377	.030	.485	.030	.405	.025	.438	.037	.293	.235	.229	.293
55,000	.414	.037	.513	.028	.434	.029	.476	.038	.330	.263	.258	.331
60,000	.455	.041	.546	.033	.465	.031	.522	.046	.371	.296	.289	.377
65,000	.504	.049	.582	.036	.498	.033	.564	.042	.420	.332	.322	.419
70,000	.559	.055	.627	.045	.543	.045	.633	.069	.475	.377	.367	.488
75,000	.616	.057	.675	.048	.585	.042	.716	.083	.532	.425	.409	.571
80,000	.761	.145	.782	.107	.683	.098	.839	.123	.677	.532	.507	.694
85,000	.963	.202	.936	.154	.816	.133	1.068	.229	.879	.686	.640	.923

The dimensions of the axle were such (Fig. 2) that when loaded to its elastic limit, the maximum fibre stress at its centre was 28,730; at 18 inches from the centre, 22,100 pounds, and at the neck of the journal, 20,600 pounds.

The axle tested was designed for use under a freight car of 60,000 pounds capacity, the car itself weighing about 20,000 pounds. Each of the four axles under such a loaded car, therefore, must withstand a static load of 20,000 pounds, which load would develop a maximum fibre stress in the centre of the axle tested of 10,810 pounds. In comparing these values with those obtained in the tests as given in the preceding paragraph, it is important to remember that the stresses to which car axles are subjected when in service arise from complicated conditions, and that their value cannot be determined from static conditions alone.

The test specimen which was forged down from the crop end of the axle, was turned down in the centre for a distance of 8.5 inches and tested under tension. The results are as follows:—

Diameter in inches,	1.875
Area of cross-section,	2.755
Total load, pounds,	140,700.
Ultimate strength, pounds per square inch,	51,070.
Elastic limit,	30,000.
Modulus of elasticity,	29,671,000.
Area at point of fracture, per cent. of original area,	61.6
Elongation in 8 inches,	27.3

Finally, one end of the test specimen was exposed to the action of acid, and the etching thus produced used in printing Fig. 5. This figure, therefore, shows the disposition and relative density of the various layers of iron composing the specimen. The symmetrical arrangement of curved lines which is so noticeable, is due, evidently, to the hammering of the round section of the axle to a square section, in the process of forging the end of the axle down to the size of the test specimen.

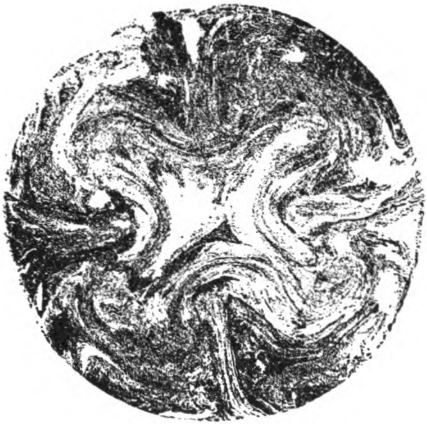

Fig. 5.

While the tests show the iron of the axle to have been of excellent quality, the most significant fact developed is that concerning the amount of distortion which such an axle will withstand, without taking a permanent set.

It would at first sight appear impossible that by loads applied at the journals, a common car axle could be deflected at its centre as much as a third of an inch without exceeding its elastic limit, but an analysis of the data given will fully justify such a conclusion. The results show also, that a deflection of the axle well within the elastic limit of the material, may be sufficient to produce a temporary change of gauge in the wheels mounted upon it, of quite three-tenths (0.3) of an inch.

NAVAL PRACTICE IN SHIP RIVETS AND RIVETING.*

By J. H. Linnard, Naval Constructor, U. S. N., Member.

AMONG the most important details of hull construction are the methods by which the different parts are attached to each other to give strength to the whole. Too much care cannot be taken to secure such arrangements as will provide strength combined with cheapness of execution. Too often in ship-yards insufficient attention is given to this matter, and while general indications as to the riveting are usually put on plating plans, the details of spacing, etc., in important connections are frequently left to the judgment of foremen, or, indeed, the iron-worker who lays out the work.

In merchant work Lloyd's rules have been adopted as the general standard, but they fail to give information in several particulars. Thus the spacing of rivets in the angles uniting water-tight frames and bulkheads to the outer skin plating is not specified. No information is given as to what is considered a suitable size of rivet head, etc. In the hulls of the very large passenger steamers these matters have assumed great importance, and we hear of riveting proving defective and of rivets having to be cut out and replaced more frequently than in times past.

In men-of-war, where scantlings have been cut down to the lowest limit of safety, the detailed consideration of the riveting becomes of capital importance. In such work, where weight-saving without sacrifice of strength becomes so necessary, certain departures from merchant practice as exemplified in Lloyd's rules have been very general in the different navies. These relate principally to the breadth of laps and straps, connection of frames to outside plating, the shape of rivet heads, etc.

In our own navy it has been the practice to follow in general the rules of the British Admiralty. Some years ago, in the course of the work in which I was then engaged, it became desirable to draw up rules for riveting for the guidance of draftsmen and foremen in considerably greater detail than any given in the government specifications. At that time the available information on the subject was collated, the practice in different services compared, and the results embodied in a series of tables which have since been adopted, with some minor modifications, in a number of yards in which our new vessels have been building. It has been thought that these tables might be found of interest to the Society, and might lead to a profitable discussion as to whether modifications in them are desirable.

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* A paper read at the fourth general meeting of the Society of Naval Architects and Marine Engineers, New York, November 12th, 1896.

In no particular of riveting work is greater diversity shown than in the shapes of the rivet heads. This is due to the fact that, in by far the greater part of riveted connections, the principal stress on the rivets is a shearing stress, and the heads are usually more than ample to resist the forces exerted on them. Where it is necessary to study weight-saving, the size and shape of the rivet head becomes of considerable importance. In a vessel such as the armored cruiser "Brooklyn," the weight of rivets driven is upward of 330,000 pounds, and of this weight from one-fourth to one-third is in the rivet heads. Any method by which any considerable percentage of weight can be saved in the heads is, therefore, worthy of consideration.

The rivet head which has the least weight is the countersunk head, since practically all of the head is simply a replacement of metal taken from the plate. It has, however, the disadvantages of increased cost due to the labor of countersinking, and the decrease in the tensile strength of the plate or shape, owing to the greater section of metal removed from the hole. In the French service the saving of weight is considered of sufficient importance to counterbalance these disadvantages, so that the greater part of the riveting, except very light work, is executed with countersunk heads. In our own navy such heads are only used where the character of the work requires it on other grounds. It should be pointed out that where countersunk heads are used it is important that they should fit the countersunk holes in the plate. The angle at the apex should be a very little sharper, so that the head will be sure to bottom well. The blow of the hold-up will then cause the head to completely fill the countersink.

In Fig. 1 are shown the dimensions of the different shapes of rivet heads adopted. The pan heads are those adopted by the British Admiralty. The tap rivet heads have squares on them of dimensions determined by experiment. They are the minimum necessary to

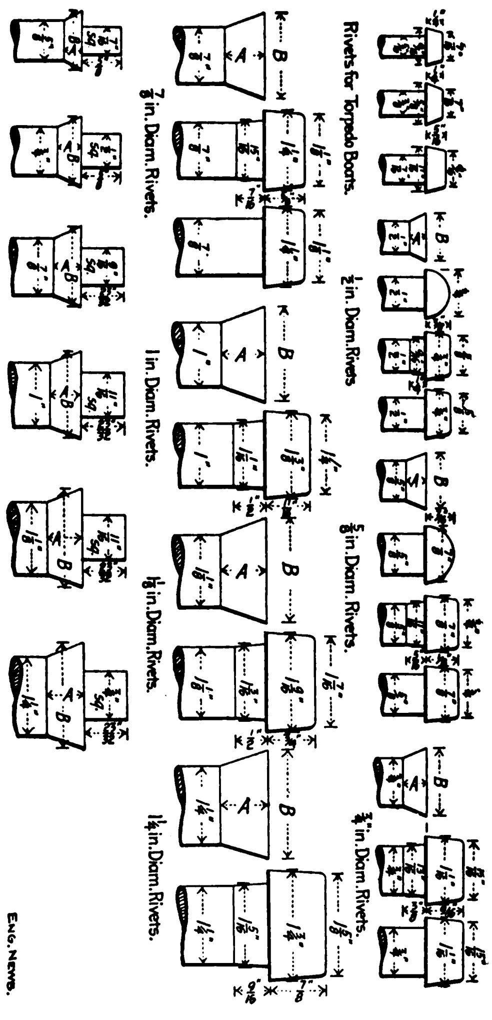


FIG. 1.—STANDARD RIVET HEADS IN USE BY THE BUREAU OF CONSTRUCTION AND REPAIR, U. S. NAVY.

(For all countersunk head and tap rivets make dimension A equal thickness of plate plus 1-16 in. Dimension B as per angle of countersink for given depth of head. Tap rivets will be ⅛-in. larger than the corresponding rivets for the same thickness of plate; except those in stem and stern post, which will be ¼-in. larger.)

set the rivet home strongly without wringing off the square with the wrench. It has been found by our own rivet makers that it is difficult to get these pan heads sufficiently well centered on the shanks of the rivets to meet the requirements of the inspectors.

The Bureau of Construction and Repair considers it of vital importance that these cone-head rivets should be true to figure. A slight eccentricity of the rivet holes is sometimes unavoidable, and if the closing rivet itself should also be eccentric, the lip would not cover as it ought, and therefore, whenever there is eccentricity apparent to the eye, the rivet must be rejected. Experienced rivet makers with the best appliances have found it practically impossible to make rivets with these heads absolutely concentric. The shortest diameter of the head is considerably greater than the diameter of the rivet blank. The result of the heading operation is that if there is the slightest crookedness in the blank, or if it is not sheared perfectly square, the head will be formed unavoidably on either one side or the other of the centre line of the rivet, because the rivet blank is free to wabble about, and is not held centrally as it should be by the heading die. A rivet head whose shortest diameter is exactly equal to that of the rivet avoids this difficulty, because if the rivet blank is bent, or in anywise eccentric or sheared obliquely, it will be caught by the header and straightened up and the head formed true and central in every instance. This is the form of cup largely used in making boiler rivets.

Years ago the government adopted a standard for bolts and nuts, including form of threads, and this standard has been of great use not only to manufacturers of bolts, but to engineering establishments throughout the country, most of whom have adopted it. In a similar way, if the Navy Department were to establish a consistent standard for forms of rivets, it would also, no doubt, be adopted by other users of rivets throughout the country, with equal advantage.

A large manufacturer of rivets writes:

"The proportions we adopted for our boiler rivet heads several years ago, and which have been used ever since with the greatest satisfaction, are as follows: The height of cone head is ⅞ the diameter of the rivet shank. The least diameter of cone head is equal to the diameter of the rivet shank. The greatest diameter of cone head and button head, 1¾ times the diameter of the rivet shank.

"The height of the head of button-head rivet is equal to ¾ the diameter of the rivet shank."

U OF M

This manufacturer suggested the adoption of these heads for hull-riveting also.

It will be observed that the rivet head proposed is considerably heavier than the Admiralty head. With the authority of the Bureau of Construction and Repair, a new type of rivet head has been adopted for the most recent vessels. They are substantially as follows: The diameter of head at top is equal to the diameter of rivet, at bottom is 1⅝ diameters; and the height is ¾ of the diameter of shank. These heads are substantially identical in weight with the Admiralty heads, except for the smaller sizes, which are from 5 to 10% heavier. The detailed dimensions of these heads are shown in Fig. 2. They have proved amply strong in use and are easily manufactured. It is possible that the height of the head could be still slightly reduced.

TABLE I.—RELATION BETWEEN DIAMETER OF RIVETS AND RIVET HOLES AND WEIGHT OF PLATES.

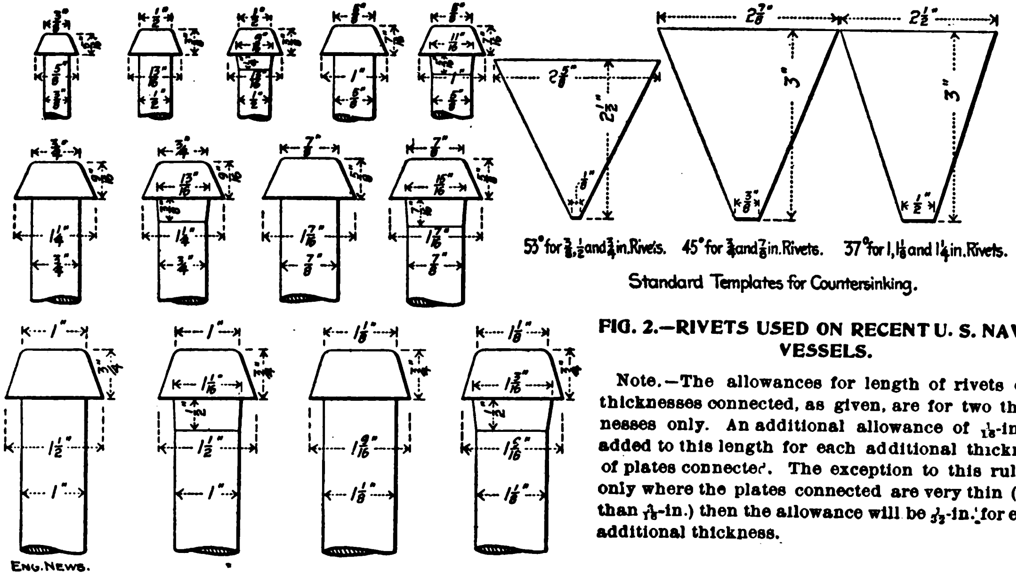
Weight of Plates.	Diameter of rivets. ins.	Corresponding rivet holes. ins.
Up to 6 lbs. exclusive,	⅜	7-16
6 " 8 " "	½	9-16
8 " 13 " "	⅝	11-16
13 " 20 " "	¾	13-16
20 " 30 " "	⅞	15-16
30 " 40 " "	1	1 1-16
40 " 61 " "	1⅛	1 7-32
61 lbs. and above,	1¼	1 11-32

TABLE II.—BREADTHS OF LAPS AND STRAPS FOR RIVETING.

(Centres of rivets to be placed not less than 1⅝ times the diameter from the edges. In double and treble riveting, the distance from centre to centre of rows to be not less than 2¼ diameters in laps, and 2½ in straps.)

Breadth of laps for single riveting,	3¼	diameters.
Breadth of laps for double riveting,	5½	"
Breadth of laps for treble riveting,	7¾	"
Breadth of edge strip for single riveting,	7	"
Breadth of butt-strap for double riveting,	11½	"
Breadth of butt-strap for treble riveting,	16½	"

In sizes above ½ in., intended to be driven in punched holes, there is a taper enlargement under the head, the diameter just under



53° for 3/8, 1/2 and 3/4 in. Rivets. 45° for 3/4 and 7/8 in. Rivets. 37° for 1, 1 1/8 and 1 1/4 in. Rivets.

Standard Templates for Countersinking.

FIG. 2.—RIVETS USED ON RECENT U. S. NAVAL VESSELS.

Note.—The allowances for length of rivets over thicknesses connected, as given, are for two thicknesses only. An additional allowance of 1/16-in. is added to this length for each additional thickness of plates connected. The exception to this rule is only where the plates connected are very thin (less than 3/16-in.) then the allowance will be 1/32-in. for each additional thickness.

	DIAMETER OF RIVETS—INCHES.									
Type of points.	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4
	ALLOWANCE FOR LENGTH OF RIVETS, OVER THICKNESSES CONNECTED=INCHES.									
Countersunk.	3/8	3/8	7/16	7/16	5/8	3/4	3/4	7/8	1	1 1/16
Mashed.	7/16	7/16	1/2	1/2	5/8	3/4	7/8	7/8	1	1 1/16
Button,				1/2	5/8	3/4	7/8	7/8.		

the head being 1-16 in. greater than that of the rivet, and tapering down in about half a diameter. This taper under the head is better adapted to fill the hole made by the punch than the straight shank. It has been claimed by some that they are more troublesome to drive, but no difficulty has been found by those who have adopted them, and they unquestionably add materially to the strength of the riveting by better filling the rivet holes.

In table S. 8 of Lloyd's rules is indicated the shape of countersunk points required for outside plating. This requirement cannot be practically carried out with exactness, for it requires a different angle

TABLE III.—SPACING FOR RIVETS.

Connection.	Number of diameters from centre to centre.	
Single-riveted laps and straps,	3½	+
Double-riveted laps and straps 15 lbs. and over,	4	—
Double-riveted laps and straps under 15 lbs.,	4	+
Treble-riveted laps,	4½	—
Treble-riveted straps with alternate rivets in third row omitted,	4	—
Longitudinal seams of plating required to be water-tight,	4½	—
Connections of transverse frames not water-tight to outside plating,	8	+
Deck plating to beams, and in general where special strength is not required,	8	—
Connections of floor-plates, brackets, lightened intercostals, etc., to clips and angles,	7	—
Connections of vertical keel angles where not water-tight, of angles and other stiffeners to bulkheads, of boiler and engine bearings and foundations generally,	6	—
Connections of inner-bottom plating to all non-water-tight frames and longitudinals,	5	+
Connections of angles of water-tight frames and longitudinals to all plating, and in general where water-tightness is required between plates and shapes,	5	—
Connections of armor-shelf angle to shelf and outside plating,	4½	—
In special cases of intercostals, beam ends, etc., where strength is required in connections of limited extent, spacing to be as required by circumstances, except that rivets in the same line should never be spaced less than,	3	

NOTES.—The sign + indicates that if the exact spacing cannot be used take the nearest over. The sign — indicates that if the exact spacing cannot be used take the nearest under.

A reasonable discretion should be used in connection with the signs + and — of the table, and where the spacing as laid off comes quite close to the requirements, but with the wrong sign, it will generally be better to use it than to depart too widely from the exact spacing in the direction indicated by the sign.

of countersink for each size of rivet and each thickness of plating. After some experiments, it was found that the countersinks could be greatly simplified. The angles adopted are indicated in Fig. 2. The trapezoids shown give convenient dimensions from which templates can be made for keeping the countersunk tools true. It will be observed that the 45° countersink answers for three-quarters of all rivets driven in a ship-yard.

It is intended that the rivet holes should be countersunk through the plate to within 1-32 inch of the bottom of the hole in all cases. This has the advantage of removing most of the metal weakened by the punching.

This varying depth of countersunk holes leads to some slight inconvenience in ordering countersunk-head rivets, and it has been proposed to fix standard depths as follows:

Diameter rivet, inches,	½	⅝	¾	⅞	1	1⅛
Depth countersunk, inches,	5-32	7-32	11-32	½	⅝	¾

The relation of the diameters of rivets to thickness of plates and shapes is regulated by a number of conditions. The rivet hole must not be too small to be punched through the plate. It must not be too large as to crush down the plate before shearing. It must not be so large as to require placing so far back from the edge as to prevent satisfactory calking. For a given thickness of plate, the strongest joint is obtained by the largest permissible rivet. The rivets must not be too large for ready hand driving. Out of these conditions there has grown up a tolerably uniform practice for ship work in all countries. The introduction of steel plates and steel rivets caused an augmentation of the size of rivet relatively to the plate, owing to the relative weakness of steel rivets to steel plates as compared to iron rivets in iron plates.

Table I shows the sizes adopted.

In cases where a rivet connects different thicknesses of plating together, the size of the rivet indicated for the greater thickness is to be used, provided it is not more than ⅛-inch larger than the size of rivet required for the lesser thickness. But in no case is the rivet to be less in diameter than the thickness of the thickest plate. Tap rivets will be ⅛-inch larger than the corresponding rivets for the same thickness, except those in stem and stern post, which will be ¼-inch larger.

Table II gives laps and straps suitable for plating. The widths are cut down from the requirements of Lloyd's rules, resulting in a considerable saving of weight. It is believed they are sufficient with first-class workmanship.

Table III shows the rivet spacing adopted. The endeavor has been made to make it sufficiently detailed to provide for the greater part of the cases arising in hull work.

Where strength is required in laps and butted connections of plating, with the spacing indicated, single riveting is suitable only for plating under 12½ lbs., and double riveting under 25 lbs. Where strength is required in connections above 30 lbs., a special calculation should be made, and generally quadruple riveting will be required.

The tables of spacing have been slightly modified from those originally determined upon in the direction of closer spacing, which has seemed desirable, in view of the comparative weakness of the steel rivets used in the navy.

In the French navy a very elaborate series of rules for spacing of rivets in butts, laps, etc., has been adopted. These include the general use of staggered riveting, usually an irregular spacing of rivets in different rows, and, in special cases, the use of different sizes in the same joint. Some additional strength is doubtless thus obtained in the connections, but it does not appear worth the increased cost. The simpler methods of chain riveting have always been adopted by the British Admiralty and in our own service.

It has been mentioned above that on account of the comparative weakness of the steel rivets used in the navy, it has seemed desirable to decrease the spacing. The requirements for rivet steel for the first steel cruisers were a minimum tensile strength of 60,000 lbs. per sq. inch, and an elongation in 8 inches of not less than 23 per cent., with a shearing strength of not less than 50,000 lbs. per sq. inch. The actual average results obtained from the tests were 64,740 lbs. per sq. inch, and 27.41 per cent. elongation, with an average shearing strength of 53,695 lbs. per sq. inch.*

The requirements for the recent ships have been between 55,000 and 62,000 tensile lbs., with a minimum elongation of 29 per cent. in 8 inches, and a minimum shearing strength of 45,000 lbs. per sq. inch. I am not informed as to the average results actually obtained, but with the limits between which the tensile strength is required to be maintained, the average shearing strength cannot exceed about 50,000 lbs. It seems very desirable to make a return toward the earlier specifications and sacrifice a little of the ductility in order to obtain increased shearing strength. A rivet steel for hull work, similar to the requirements of the present specifications for rivets for longitudinal boiler seams, appears very desirable. These requirements are between 58,000 and 67,000 tensile strength, with a maximum elongation of 26 per cent. in 8 inches. The maximum allowances of sulphur and phosphorus, which for hull rivets are .04 and .05° respectively, are for these boiler rivets .035 and .04 respectively, and with a metal of this character no difficulties should occur in the satisfactory driving of the rivets.

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*Report of the Naval Advisory Board on "Mild Steel, etc.," prepared by Assistant Naval Constructor R. Gatewood, U. S. N., Washington, Government Printing Office, 1886.

A NEW TEST OF THE RATE OF SETTING CEMENT.

By William S. MacHarg.

ALTHOUGH the Vicat needles have for so long a time been accepted as the standard means for determining the rate of setting of cements, they have held that position because nothing so readily applicable and capable of showing more of the process of setting has presented itself, rather than because the needles were altogether satisfactory to investigators. This is evident from recent inventions intended to make a continuous application of this test by wheels or by needles operated through the whole time by clockwork. That this desire for some test showing more definitely and completely the process of setting is not of recent origin is shown by the following from *Portland Cements for Users* (London, 1894), by the late Mr. Henry Faija:

"It may be well . . . to decide on what is meant by the word set. In general the word is used to express a period when a substance originally in a liquid, semi-liquid, or glutinous state has attained the ultimate hardness due to its nature, and if it is desired to express an intermediate period, the qualification 'sufficiently' is added. With cement, however, which may not attain its ultimate hardness for years, the word 'set' has a somewhat different signification, and it is understood that a cement 'sets' in a few minutes or hours, after which it hardens. The means usually employed to fix the period when the setting is completed and the hardening commences are, in the author's opinion, rather at fault, inasmuch as it is the hardness of the sample which by the process alone is considered, either by pressing it with the thumb-nail or by using a Vicat needle.

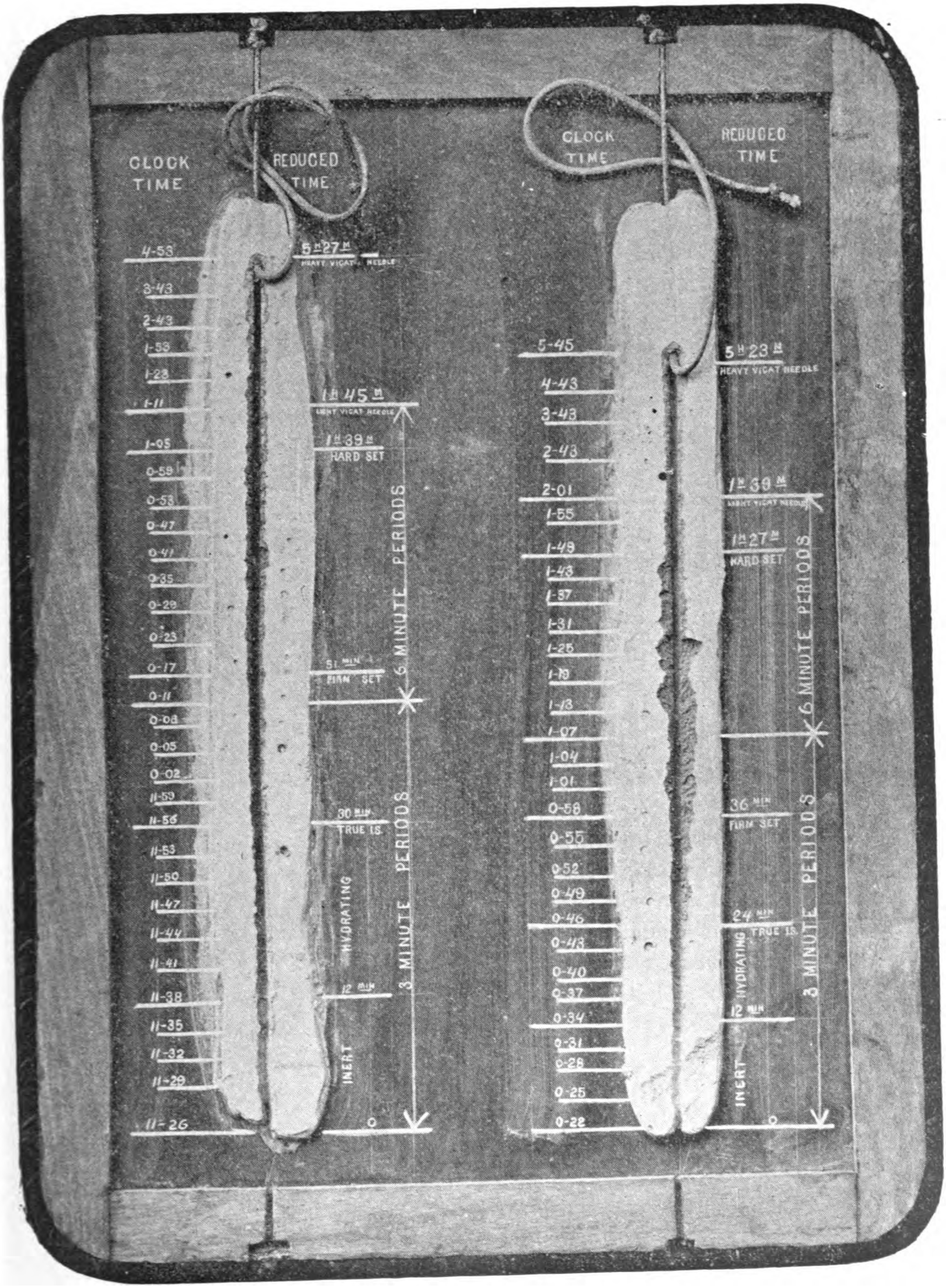
"As previously stated, the setting of a cement is purely chemical in its action; it is commenced with the addition of the water to the cement, and continues until the cement has attained its ultimate hardness. Continuous, however, as this chemical action may be, there are periods, at all events, during the early stages that may be defined, and it would appear desirable to express by the word 'set' one of these periods.

"When a cement is gauged and made into a pat or briquette, the first change observable is that the water comes to the surface, the next that the water is absorbed by the cement, the sample will then begin to heat, and, lastly, it will gradually return to its original, or what may be called its normal temperature, and it is this last period that may with justice be understood by the word 'set.' It has nothing to do with the hardness, as some cements will be hard enough to withstand the impress of the thumb-nail before, and some not until long after, the time when the author considers a cement 'set.'"

I quote this at length as the best expression that I know of the process of setting in cement, the want of an adequate method of determination of periods in the same, and the actual relation of the Vicat needle test to the process of setting.

It is evident to any one who has studied the subject that most or all Portland cements, subjected to the ordinary test, have set a distinct and considerable time before the light Vicat needle is perfectly supported—that is, supported without a mark. This makes necessary the exercise of judgment as to the real activity of a cement, which it is desirable to eliminate, both as a cause of difference of opinion and to secure uniformity of method. In the above quotation Mr. Faija has indicated a period and a means of its determination much more nearly correct, but the fixing of the time of total absorption of water from the surface of a pat, while it may be done, still requires the use of judgment, and persons may differ materially in what they consider total absorption.

The explanation given by Mr. Faija of the process of setting, and his selection of the period when the cement may be considered set,


CLOCK TIME
REDUCED TIME
4-53
5H 27M
HEAVY VICAT NEEDLE
3-43
2-43
1-53
1-28
1-11
1H 45M
LIGHT VICAT NEEDLE
1-05
1H 39M
HARD SET
0-59
0-53
0-47
0-41
0-35
0-29
0-23
0-17
51 MIN
FIRM SET
0-11
0-08
0-05
0-02
11-59
11-56
30 MIN
TRUE I.S.
11-53
11-50
11-47
11-44
11-41
11-38
12 MIN
HYDRATING
11-35
11-32
11-29
INERT
11-26
0
6 MINUTE PERIODS
3 MINUTE PERIODS
CLOCK TIME
REDUCED TIME
5-45
5H 23M
HEAVY VICAT NEEDLE
4-43
3-43
2-43
2-01
1H 39M
LIGHT VICAT NEEDLE
1-55
1-49
1H 27M
HARD SET
1-43
1-37
1-31
1-25
1-19
1-13
1-07
1-04
1-01
0-58
36 MIN
FIRM SET
0-55
0-52
0-49
0-46
24 MIN
TRUE I.S.
0-43
0-40
0-37
0-34
12 MIN
HYDRATING
0-31
0-28
0-25
INERT
0-22
0
6 MINUTE PERIODS
3 MINUTE PERIODS

are satisfactory. The same period, however, is fixed by the definition that "a cement is set when the mass no longer admits distortion without fracture," and this, I think, is the true definition. This condition, also, being a distinct stage in the progress from paste to eventual hardness, admits the application of a mechanical test for its determination. From this conclusion I sought a mechanical test, easily applied, and devised that shown in the cut, which, from its simplicity, and the clearness with which it shows all the physical characteristics of the cement in sequence, during the time of its application, may, I think, prove valuable.

An ordinary school slate is used, notched at opposite ends to hold a flexible cord, which is stretched across so as to lie on the surface of the slate. Cement paste, made by adding 25 per cent. of water to clear cement, well worked, is then plastered over the cord as shown, covering it a little more than its own diameter, and troweled smooth. Marking at one end of the pat the time the troweling is finished, the cord is loosened at this end, and at periods of three minutes is gently lifted from the cement in spaces one-quarter inch to three-eighths inch long, marking the space and time at the side as shown. After the cement has set the periods of time are lengthened (the spaces remaining the same length) to six minutes, then twelve minutes, and finally to much longer periods, so that the whole may be completed in the length of the slate. The result is eminently satisfactory; in the hardened cement is recorded every phase of the process of setting, and the periods of change may be determined very closely.

In the example shown in the cut, for the purpose of illustration, the test by the Vicat needles also is carried on, and the test by the cord is continued until the heavy needle is perfectly supported. It is to be noted that the true initial set, or time when fracture commences, occurs more than an hour before the light needle is perfectly supported, in both instances. The cements used in this test were both of American manufacture, one being a true Portland and the other a so-called natural Portland.

Referring to the cut, four stages in the early setting of cement are distinctly shown, each with characteristic markings; (1) an inert period, during which the particles are apparently arranging themselves for the coming change, and the cord lifts as out of semi-liquid mud; (2) a period of hydration, while the water is being absorbed, during which the cord lifts as from stiff mud, without cohesion; (3) a period of mild set, or initial set, with perfect cohesion, during which period the cord brings away the cement with definite and clearly-marked fracture, usually involving some width of the pat; (4) a period of hard set, when the cord comes away with a much shorter fracture of the cement, making a narrower groove in the face of the pat. In the second sample in the cut this characteristic change in the fracture is very plainly shown, but in the first also, and in the several tests I have made, this change is distinctly marked. With a quick-setting cement tried in one experiment, the third period was found to be extremely short.

The beginning of the third period is determined by this method, agrees very closely with the conditions pointed out by Mr. Faija as denoting the occurrence of initial set, and I think this should be taken as the time of initial set. The condition of the mass at the beginning of the fourth period may indicate that this is the point at which commences that final chemical process which we know as the "hardening" of cement.

It is evident that by the application of a train of clockwork this test may be made automatically and continuously. Affairs forbid that I should take the time necessary to establish the relations which may exist between the periods shown in this test, and the qualities of cements, but I hope that the experiment may be tried by others more directly interested in this material, and I shall be pleased if the method is found of value.—*Engineering News, January 7th, 1897.*

CHICAGO, ILL., December 23d, 1896.

THE FATIGUE OF WROUGHT IRON AND STEEL.*

From Railroad Gazette, January 22d, 1897.

IT has been shown by experiment that wrought iron and steel can be loaded and unloaded an indefinite number of times without rupture if the amount of the changed load does not exceed a certain proportionate part of its ultimate strength, and that as this change of load decreases the maximum load may increase. All this is shown graphically in Fig. 1, where the shaded area represents the working field, or the limits of stress between which the material (in this case 60,000 pounds steel) can be loaded and unloaded (in part) an indefinite number of times without failure. That is to say, when the changes in load are not greater than those indicated by the shaded part of this figure, the numerous micro-flaws do not enlarge, and hence the gradual fracture, indicated by the word "fatigue" does not develop. In no case does the material become any more crystalline than it was originally. When the load is wholly removed each time, the material can be worked (loaded and unloaded) between zero and the "repetition limit," which is commonly taken as one-half the ultimate strength, or, in this case, 30,000 pounds per square inch. When the load is wholly reversed each time, as in the case of a railroad axle, then the stress changes from tension to an equal compression and back again an indefinite number of times, and then the metal

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* From a paper by Prof. J. B. Johnson, before the St. Louis Railway Club.

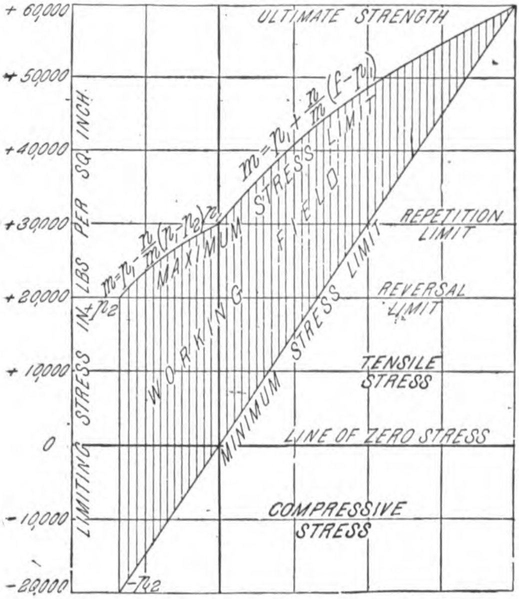
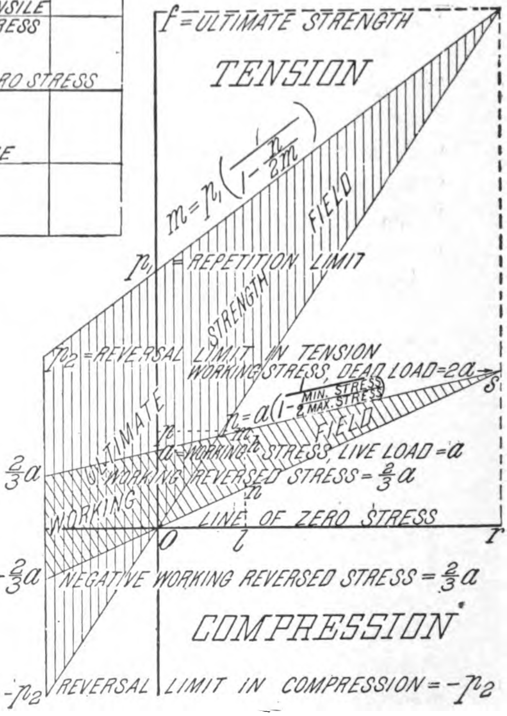


FIG. 1.



f = ULTIMATE STRENGTH
TENSION
$m = n_1\left(\frac{1}{1 - \frac{n}{2m}}\right)$
FIELD
n_1 = REPETITION LIMIT
STRENGTH
ULTIMATE
WORKING
n_2 = REVERSAL LIMIT IN TENSION
WORKING STRESS, DEAD LOAD = $2a$
s
$n = a\left(1 - \frac{1}{2}\frac{\text{MIN. STRESS}}{\text{MAX. STRESS}}\right)$
n
m
FIELD
a = WORKING STRESS, LIVE LOAD = a
$\frac{2}{3}a$
WORKING REVERSED STRESS = $\frac{2}{3}a$
n
LINE OF ZERO STRESS
0
l
r
$-\frac{2}{3}a$
NEGATIVE WORKING REVERSED STRESS = $\frac{2}{3}a$
COMPRESSION
$-n_2$
REVERSAL LIMIT IN COMPRESSION = $-n_2$

FIG. 2.

can be stressed in each direction to the "reversal limit," which is taken at one-third the ultimate strength, as shown in Fig. 1.

When a factor of safety is to be introduced, this working field takes the position shown by the diagonally-shaded area in Fig. 2. Thus, with a factor of safety of three, loads may be imposed and removed an infinite number of times up to 10,000 pounds per square inch; but if the load is to be reversed in direction indefinitely, then the load must be limited to 7,000 pounds per square inch if a factor of safety of three is to be used with low carbon steel. With wrought iron the repetition limit may be taken at 24,000 pounds, and the reversal limit at 16,000 pounds per square inch.

MECHANICAL PROPERTIES OF IRON AND STEEL.

A PAPER entitled "The Mechanical Properties of Wrought Iron and Steel, as shown by Actual Tests," was presented before the St. Louis Railway Club at its November meeting by Prof. J. B. Johnson of St. Louis. Illustrations were offered in the form of lantern slides exhibiting specimens and test work which had been conducted by the author in the laboratories of Washington University. The following paragraphs taken from the paper will be found interesting:

When the general adoption of the Bessemer process of making steel had led to its reduction in price, so as to become a competitor of wrought iron, and when it was shown that the usual mechanical tests revealed an equally soft and much tougher material, steel began to replace wrought iron in a thousand ways. And as it had never been found necessary to apply scientific tests to, or to make chemical analyses of, wrought iron, so it was supposed the steel could be purchased in the open market with equal security. An untold number of astonishing and unexplained failures of Bessemer steel in rails, boilers, axles, shafts, etc., has now thrown suspicion on all kinds of steel when used under the most trying conditions, and the object of this paper is to restore confidence in this material by explaining some of the causes of its failure, and by showing how to avoid them. It is now commonly regarded as more or less treacherous, but I shall hope to show that when purchased under the ordinary conditions as to inspection now prevalent in this country, and under reasonable specifications, neither of which limitations will appreciably increase the cost, a far more efficient and reliable material may be obtained, and at less cost than would result from the continued use of wrought iron.

The conclusions offered in this paper are based on actual tests, the geographical representation of many of which will be shown on the screen. But before beginning with these I wish to give my views concerning the endless controversy about the cold crystallization of iron and steel, in service, from shock, vibration, or what not. Concerning steel little need be said in this connection besides the general fact that all steel, whether simply cast or cast and rolled while hot, is always and under all circumstances wholly crystalline. It always crystallizes in the process of cooling, and it cannot be obtained cold in any other form. When pulled apart in a testing machine, or bent cold in the full section and broken, it shows a fine silky fracture, which leads to the impression that the structure is fibrous. This appearance is produced by the cold drawing out, and is not the normal molecular arrangement. When nicked or grooved by a V-shaped tool, and broken across, it always reveals a crystalline fracture.

Concerning wrought iron, however, the case is different. Its production from a puddle-ball is like the formation of butter in the bath of buttermilk, or like a sponge dipped in molasses, and when it is squeezed and rolled the adhering slag forms into separating sheaths about the nearly pure iron filaments, thus giving to the structure an essentially fibrous character. Each filament of pure iron is a series of very small and distorted crystals, but these are not visible to the naked eye. It is common, however, in the cheaper grades of wrought iron, to find on a broken cross-section large crystalline areas, and sometimes nearly the entire section presents this appearance.

There are three general causes of this crystalline structure: First, the so-called wrought iron may have been rolled from faggoted scrap, some of which was probably high-carbon steel, and this portion would show a crystalline fracture. Second, the puddle-ball may have been formed under too great a heat (a common fault), so that a portion of it had been actually melted, thus forming of this portion ingot metal or steel, which part would, when cold, be wholly crystalline. Third, the puddling process may have been incomplete, when, with a low fire, some of the unreduced pig iron would be removed with the ball, and this would form a coarsely crystalline portion of the final rolled bar. Concerning the cold crystallization of wrought iron, however, my views are as follows:

1. The normal molecular arrangement of wrought iron is crystalline, but the thorough admixture of the inert slag in a well-worked product prevents these crystals from forming in visible sizes. The ordinary fracture, therefore, exhibits rather a lateral view of these finely crystallized threads, thus causing this to present a fibrous appearance.

2. From one or more of the three causes named above a large part of any so-called wrought-iron bar may be actually and coarsely crystalline from the time of its first cooling.

3. With the ordinary and more inferior grades of wrought iron now on the American market, it is very common to find large portions of the cross-sections of test-bars showing a crystalline fracture, even for tension test specimens of standard form. Much more, therefore, are such irons likely to have this appearance when nicked and broken across, or when nicked and pulled in tension.

4. All wrought iron, when broken with extreme suddenness, will show a crystalline fracture. This is because time is not given for the drawing out of the section, rupture occurring directly across the fibres, so that the fracture shows only the end view of the same.

5. When a bar is nicked with a sharp chisel, or grooved in a lathe with a sharp pointed tool, and broken across, rupture begins at one side without any elongation of the fibres, and extends from fibre to fibre across the section in such a way as to produce a result similar to that caused by an instantaneous rupture. In this way wrought iron will often show a crystalline or granular fracture, when, under the ordinary tensile tests, it would be wholly fibrous. All steel or ingot metal will always show a crystalline fracture when treated in this manner, although for the soft and medium grades of steel the fracture is always fibrous or silky when broken in tension, with the usual accompanying elongation and contraction.

6. Much of the so-called wrought iron on the market to-day consists simply of rolled faggots of "scrap iron," a large portion of which is scrap steel. As these are heated only to a welding heat and then rolled into merchant bar there is no real mixing of the several metals and the several components form so many separate portions of the cross-section of the final rolled forms. The crystallized steely areas found in the fracture of most ordinary wrought irons to-day can be largely traced to this source. Wrought-iron railway axles and other large forms are usually made up in this way.

7. When wrought iron breaks in service, therefore, and shows a coarsely-crystalline fracture it does not prove, to my mind, that crystallization has occurred in service. It proves only that this iron has such a structure originally. If, however, the rupture occurs in practice in a suddenly-contracted area, as in a screw thread, or in a sharp angle, or if it has been produced with extreme suddenness, as in case of explosion or shock of any kind, if the appearance of the fracture is finely crystalline or granular, this appearance may be wholly due to the method of failure. This is shown by the fact that if a specimen be cut from the adjoining metal and tested in tension with the standard form of specimen it may show a wholly fibrous fracture. In such cases, therefore, the crystalline appearance of the fracture is due to the particular conditions as to shape of specimen and the suddenness of rupture and not to any molecular change which has taken place in the iron.

8. The following is taken from the annual report of tests of metals, made at the United States arsenal, at Watertown, Mass., for 1890, in which are recorded in many tests of specimens cut from the journals of old railway axles: "Wrought-iron axles have been examined which have had long-continued service, the journal of which showed incipient cracks, indicating that rupture had begun, and that further use must result in complete rupture. It is a remarkable fact that the tests of the metal of these journals near their cracks show no loss of strength or ductility. No indications of a tendency to crystallize were discovered, and inasmuch as the metal has gone through all the phases of deterioration up to the limit of actual rupture without showing a crystalline tendency, it is thought this demonstrates and proves that this material is incapable of cold crystallization when exposed to the conditions of service."

In one instance one of the old cracks, which had developed at the inner shoulder of the journal reached to a depth of 0.02 inches into the side of the test specimen, and yet the specimen broke 2 inches from this section. After rupture the ends of the specimen (1⅛ inches diameter) containing this crack was bent cold 33° with "this crack at the middle of the bend on the tension side, which opened the crack in width, and also developed numerous other cracks in the vicinity," but without rupture. All the tests showed fibrous fractures.

ABSORPTION OF WATER BY BUILDING MATERIALS.

WHEN placed in water, gypsum, burnt, pulverized, and made into a block, absorbs 400 to 425 grammes* of water per cubic decimeter;† cement and flag-stone 80 to 200 grammes; limestone, soft or coarse, 140 to 325 grammes; mosaic of hydraulic lime mortar and crushed flint, 200 grammes; limestone, hard, 120 to 170 grammes; different varieties of mill-stones, 80 to 200 grammes; slate, 10 to 90 grammes; roofing tiles, 26 to 290 grammes; bricks, 60 to 325 grammes; clinker-plates, 20 grammes; sandstone, 15 grammes; stoneware, 5 to 10 grammes; oak, 45 grammes; pine, 50 grammes.

The absorption of water to complete saturation does not take place in equal periods and with the same rapidity. Least moisture is absorbed by certain varieties of slate, roofing tiles, bricks, clinker-plates, stoneware, and wood, and as these materials also dry in the shortest time, they would be most suitable for building purposes.—*Thüringer Baugewerbe Anzeiger.*

INVESTIGATIONS REGARDING THE HARDENING OF STEEL.

A NUMBER of experiments made by G. Charpy show that the temperature at which, in hardening steel, a change in the properties takes place, moves within very narrow limits, and lies somewhat above 700° C. By heating below 700° hardening is not effected, while heating to above 750° or at all events up to 800° is useless, and sometimes even injurious. Hardening increases the elastic limit, the tensile strength, and the strength of flexure, but reduces the malleability and tenacity. Brittleness by shock decreases in medium hard steels but increases in hard varieties. A content of nickel, chromium, manganese, or tungsten have a favorable effect. The degree of the effect upon the properties of the metal depend partly on the rapidity of cooling and partly on the composition of the steel. A content of carbon is necessary. The other substances mentioned above cannot by themselves render the steel capable of hardening, but they enhance the influence of hardening upon the properties in carboniferous steel. The change in the crystalline structure of the iron, which was observed by determining the Osmond critical point by heating in an electrical furnace which was connected with a Le Chatelier pyrometer, galvanometer, and photographic registering apparatus, was found to be of but little importance for the success of hardening. On the other hand, the conversion of carbide carbon into hardening carbon is of preponderating influence.—*Chemisch-technisches Repertorium.*

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* 1 gramme = 0.564 drachm.

† 1 cubic decimeter = 61.027 cubic inches.

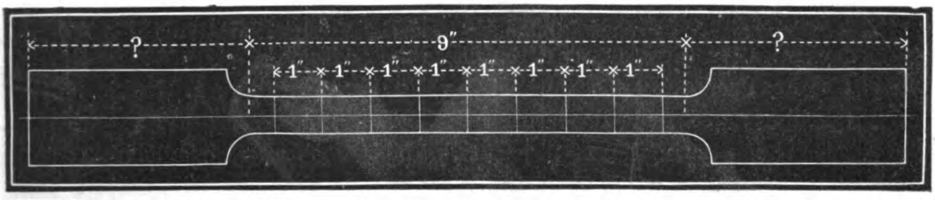
U. S. GOVERNMENT TESTS OF STEEL PLATE.

AT the regular meeting at Washington, in January, 1896, amendments were made to certain of the Rules and Regulations of the Board of Supervising Inspectors of Steam Vessels. We present, herewith, such parts as relate to the testing of steel plate:

"To ascertain the tensile strength and other qualities of steel plate, there shall be taken from each sheet to be used in shell or other parts of boiler which are subject to tensile strain, a test-piece prepared in form according to" the diagram given and described below. "The straight part shall be nine inches in length and one inch in width, marked with light prick punch marks at distances one inch apart, as shown, spaced so as to give eight inches in length." The curved parts shown are to be of one inch radius, and the ends for securing the piece in the testing machine are to be from 3 to 6 inches long (*i. e.*, the dimensions marked "?"), and 1½ to 2 inches wide. "The sample must show, when tested, an elongation of at least 25 per cent. in a length of 2 inches, for thicknesses up to ¼ inch, inclusive; and in a length of 4 inches, for over ¼ to $\frac{7}{16}$, inclusive; in a length of 8 inches, for over $\frac{7}{16}$ to 1 inch, inclusive; and in a length of 6 inches, for all thicknesses over 1 inch. The reduction of area shall be the same as called for by the rules of the Board." [The rules here referred to are as follows: "All steel plate of one-half inch thickness and under shall show a contraction of area of not less than fifty per cent. Steel plate over one-half inch in thickness, up to three-quarters inch in thickness, shall show a reduction of not less than forty-five per cent. All steel plate over three-fourths inch thickness shall show a reduction of not less than forty per cent.; *provided,* however, that steel plate required for repairs to boilers built previous to April 1st, 1886, may be used for such repairs when showing a contraction of area of not less than forty per cent."]

"No plate shall contain more than .06 per cent. of phosphorus, and .04 per cent. of sulphur, to be determined by analysis by the manufacturers, verified by them, and copy furnished the inspector for each order tested; which analysis shall, if deemed expedient by the Supervising Inspector-General, be verified by an outside test at the expense of the manufacturer of the plate.

"*It being further provided,* that said manufacturer shall also furnish a certificate with each order of steel to be tested, stating the technical process by which said steel was manufactured. It being further provided that steel manufactured by what is known as the Bessemer process shall not be allowed to be used in the construction of marine boilers. Plates over 1 inch in thickness may be reduced to 1 inch in the straight part for testing, in cases where the testing apparatus is not of sufficient capacity to test the full thickness of plate. The reduction of area and elongation must be equal to the requirement of full thickness of metal.



FORM OF TEST PIECE REQUIRED FOR STEEL PLATE TESTS.

"Provided, however, that where contracts for boilers for ocean-going steamers require a test of material in compliance with the British Board of Trade, British Lloyds, or Bureau Veritas rules for testing, the inspectors shall make the tests in compliance with the above rules. The samples shall also be capable of being bent to a curve of which the inner radius is not greater than one and a half times the thickness of the plates, after having been heated uniformly to a low cherry red, and quenched in water of 82° Fahrenheit."—*The Locomotive.*

PAINT ANALYSIS.*

By Thomas B. Stillman, Ph. D.

PAINT is a liquid preparation having a two-fold use. Primarily it acts as a protecting coating against the action of the weather, and simultaneously as a decorative agent.

The liquid is usually linseed oil and turpentine and the coloring matter or body some solid pigment, such as finely ground red oxide of iron.

It is essential in the production of a good paint that the oil used be one that, upon drying on the surface applied, should become hard, lustrous, and somewhat elastic.

Linseed oil excels all others in use for this purpose, and any sophistication thereto only deteriorates the quality.

Four qualities are essential in a paint: 1. Durability; 2. Working Qualities; 3. Drying Properties; 4. Covering Power.

The following list of pigments, with their chemical composition stated, will give an idea of the great variety that can be used in paints for outside work. The list would be largely increased were other pigments included that are used for interior decorative work only.

Red Pigments.—Indian red, Tuscan red (Fe_2O_3), vermilion (HgS), red lead (Pb_3O_4), antimony vermilion (Sb_2S_3). Iron oxide, Indian red, and Tuscan red can be analyzed by methods for iron ores.

Brown Pigments.—Umbers (Fe_2O_3, MnO_2, etc.), Vandyke brown (Fe_2O_3, carbon), manganese brown (Mn_3O_4), and sepia. The composition of sepia is as follows:

Melanin,	78.00	per cent.
$CaCO_3$,	10.40	"
$MgCO_3$,	7.00	"
Alkaline sulphates,	2.16	"
Organic mucus,	1.84	"
	99.40	"

White Pigments.—White lead ($2PbCO_3$, PbH_2O_2), lead sulphate

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* See notice of book, from which this article is taken, on page 146.

($PbSO_4$), zinc white (ZnO), sulphide of zinc white (ZnS), "lithophone." Also the following added oftentimes as fillers: barytes ($BaSO_4$), "blanc Fixe" (artificial barytes), gypsum ($CaSO_4$) strontium white ($SrSO_4$), whiting ($CaCO_3$), China clay (kaolin), and magnesite ($MgCO_3$).

Yellow and Orange Pigments.—Chrome yellow ($2PbCrO_4$), Chinese yellow (PbO, $PbCrO_4$), zinc chrome ($ZnCrO_4$), realgar (As_2S_3), "cadmium yellow" (CdS), "King's yellow" (As_2S_3), yellow ochre (Fe_2O_3, Al_2O_3, SiO_2, etc.), and Siennas (Fe_2O_3, H_2O, Mn_3O_4).

Green Pigments.—Chrome green (Cr_2O_3), copper green)$Cu\bar{A}$,) mineral green (malachite), cobalt green (ZnO, CoO, P_2O_5, etc.), manganese green (BaO, MnO_2, etc.) emerald green ("Paris green"), ($7Cu2C_2H_3O_2$, $3CuAs_2O_4$), and Brunswick green (compounded of barytes, chrome yellow, Prussian blue, etc.).

Black Pigments.—Lampblack (carbon), bone-black (carbon and Ca_3HPO_4), vegetable black, Frankfort black, coal-tar black, asphaltum black, and graphite black (C).*

Blue Pigments.—Ultramarine (SiO_2, Al_2O_3, Na_2O, S), Prussian blue, Chinese blue, or Brunswick blue ($Fe_8C_{18}N_{18}$), cobalt blue or smalts (Al_2O_3, CoO), Bremen blue (CuH_2O_2), and copper blue (CuO, CO_2, H_2O).

The various colored lakes, carmines, aniline lakes, etc., have but a limited application in Engineering Chemistry. Their methods of manufacture and assay can be advantageously studied by reference to *Painter's Colors, Oils, and Varnishes,* by George H. Hurst, F. C. S., London, 1892, pp. 249–282.

The analysis of a white paint, ground in oil, as shown in the Scheme on page 117, will indicate the method of procedure in analyses of this character. Where qualitative analysis has shown the presence of a few constituents only the Scheme can be correspondingly modified.

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* *The American Engineer and Railroad Journal,* November, 1896, p. 315, states: "Graphite mixed with an oil is chemically inert, and in drying forms a coat that adheres firmly to the metal surface. Its resistance to the action of acids and alkalies has been proven by numerous tests much more severe than the conditions of service, and its resistance to the penetrations of moisture have been equally satisfactory. Heat does not cause it to blister, and we are informed that steel chimneys painted with it have been heated to redness without decolorizing the paint. The paint has been used with success upon the hulls and decks of steel steamers, and there seems to be no conditions of service which it does not successfully meet."

ANALYSIS OF WHITE LEAD PAINTS.*

(Dry, not ground in oil.)

	1.	2.	3.	4.	5.	6.
PbO	86.35	85.93	83.77	84.42	86.5	86.24
CO_2	10.44	11.89	15.06	14.45	11.3	11.68
H_2O	2.95	2.01	1.01	1.36	2.2	1.61
Total. . . .	99.74	99.83	99.84	100.23	100.0	99.53

from which the composition of the white leads can be calculated to be:

	1.	2.	3.	4.	5.	6.
$PbCO_3$ . . .	63.35	72.15	91.21	87.42	68.36	70.87
PbH_2O_2 . . .	36.14	27.68	8.21	12.33	31.64	28.66
Moisture . . .	0.25	.	0.42	0.48	. .	. .
Total . . .	99.74	99.83	99.84	100.23	100.00	99.53

No. 1. English make. Made by Dutch process; of very good quality.

No. 2. " " " " " " " " " "

No. 3. Krems white. Made by precipitation with carbon bioxide. It is deficient in body, although of good color.

No. 4. German make. Precipitated by carbon dioxide; of good color, but deficient in body.

No. 5. German make. Made by Dutch process; a good white.

No. 6. German make. Made by precipitation of carbon bioxide; quality fair.

Lead white, ground in oil, is a common form in the market. It usually contains about eight per cent. of raw linseed oil, and has an extended use among painters, as it readily mixes with additional oil and turpentine to form liquid paint.

The brown pigments, composed principally of oxides of iron and manganese, can be analyzed in the same way as iron ores, the yellows and greens containing chromium require a special process, as given on page 51 of *Engineering Chemistry*.†

Occasionally the following determinations are made:

Water.—Hygroscopic. Heat one-half gram at 105° C., in an air-bath to constant weight.

Volatile Matter.—Heat one gram in a porcelain crucible to low redness; loss, less water, is volatile matter.

Water Extract.—(Acetates, sulphates, bichromates, or nitrates, indicating imperfect washing in manufacture.) Treat three grams with six successive portions of twenty-five cc. each, of cold distilled

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* *Painters' Colors, Oils, and Varnishes.* By G. H. Hurst, F. C. S., p. 39.

† See page 144.

SCHEME FOR THE ANALYSIS OF WHITE PAINT GROUND IN OIL.

It may contain silica, barium sulphate, lead sulphate, calcium sulphate, lead carbonate, clay, zinc oxide and sulphide,* barium carbonate, calcium carbonate, linseed oil, rosin oil,† and mineral oil.

Select a thin glass flask (150 cc.), weigh it and transfer to it about 6 grams of the paint and reweigh. (Many chemists prefer to use the Soxhlet-tube with ether for extraction of the oil. Fig. 1 shows one form of this apparatus) Add 50 cc. sulphuric ether, or petroleum ether, warm slightly, cork the flask, set aside two hours. Pour the clear ether solution upon a filter, and collect filtrate in a weighed beaker. Repeat this operation until the last ether extract is colorless. Transfer residue to filter and wash with ether.

1. **Residue** may contain $PbSO_4$, $2PbCO_3PbH_2O_2$, $BaSO_4$, $CaSO_4$, $CaCO_3$, $BaCO_3$, ZnO, SiO_2, Clay, $ZnCO_3$, etc. Dry this residue and treat with hot acetic acid in a No. 2 beaker. Dilute with water, warm, and filter.

2. **Filtrate,** contains the oils. Evaporate carefully to expel the ether and determine the weight of the oil.

If qualitative analysis has shown the presence of mineral oil, in addition to the linseed oil, proceed as follows:

Take 20 grams of the paint, exhaust with ether, and so obtain enough oil for saponification, etc.

After expulsion of the ether, add 200 cc. of an alcoholic solution of potash and evaporate until all the alcohol is expelled. Add 100 cc. water, dissolve any soap formed, and transfer all to a separatory funnel, add 50 cc. of sulphuric ether, shake well, and set aside twelve hours. The linseed oil, as soap, is drawn off in the water solution, while the mineral oil remains unsaponified in the ether.

Transfer this latter to a glass evaporating dish, expel the ether, and determine weight of mineral oil. This weight, subtracted from total weight of the two oils taken gives the weight of the linseed oil.

3. **Residue** may contain SiO_2. Clay, $PbSO_4$. $CaSO_4$, $BaSO_4$. Transfer the filter and contents to a small flask and digest, in the cold, for 12 hours with a saturated solution of $(NH_4)_2CO_3$. Filter, wash well with water. Neglect the filtrate. The residue on the filter is now treated with hot acetic acid; filter, wash well.

4. **Filtrate,** may contain zinc, lead, barium, and calcium salts. Saturate with H_2S and filter, wash with H_2S water.

5. **Residue** may contain $BaSO_4$, SiO_2, or clay. Dry, ignite in platinum crucible, and fuse with excess of Na_2CO_3. Cool, digest with hot water and filter.

6. **Filtrate,** may contain $2PbC_2H_3O_2$, $Ca(C_2H_3O_2)_2$ saturate with H_2S gas, filter.

7. **Residue.**—$BaCO_3$. Dissolve in dilute HCl, boil, add excess of solution of $BaCl_2$. Set aside two hours, filter, wash well, dry, ignite and weigh as $BaSO_4$.

8. **Filtrate,** contains the SiO_2 and Al_2O_3. Acidify with HCl, evaporate to dryness, take up with HCl and H_2O, filter, wash well.

Residue.—SiO_2. Dry, ignite and weigh as SiO_2.

Filtrate, Al_2O_3. Make alkaline with NH_4HO, boil, filter, dry, precipitate, ignite and weigh it as Al_2O_3 and calculate to clay.

9. **Residue,** contains PbS. Dry, transfer to a weighed porcelain crucible, add HNO_3, evaporate with H_2SO_4, dry, ignite, and weigh as $PbSO_4$.

10. **Filtrate,** contains CaO Boil out the H_2S, add NH_4OH, then $(NH_4)_2C_2O_4$, set aside two hours, filter, dry, ignite, and weigh as CaO. and calculate to $CaSO_4$.

11. **Residue.** — PbS and ZnS. Dissolve in HNO_3, add H_2SO_4, evaporate nearly to dryness, cool, add water, filter, wash well.

12. **Filtrate.** — Boil out H_2S, add HCl, and dilute H_2SO_4. to precipitate the barium. Filter, wash.

13. **Residue.**—Dry, ignite, and weigh as $PbSO_4$ and calculate to $2PbCO_3 PbH_2O_2$. ("Basic lead carbonate.")‡

14. **Filtrate.**—Make alkaline with Na_2CO_3, boil, filter off the $ZnCO_3$, wash, dry, ignite, and weigh as ZnO. If H_2S has been indicated by qualitative analysis, calculate to ZnO, ZnS.

15. **Residue.**—Dry, ignite, and weigh as $BaSO_4$. and calculate to $BaCO_3$.

16. **Filtrate.** Add NH_4OH to alkaline reaction, then $(NH_4)_2C_2O_4$, set aside two hours, filter, wash, dry, ignite, and weigh as CaO and calculate to $CaCO_3$.

$BaSO_4$.	SiO_2.	Clay $(2SiO_2 . Al_2O_3 . 2H_2O)$.	$PbSO_4$	$CaSO_4$.	$2PbCO_3 PbH_2O_2$.	ZnO, ZnS.	$BaCO_3$.	$CaCO_3$.	Linseed oil.	Mineral oil.

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*Zinc White is usually a mixture of ZnO and ZnS. "Lithophone," a zinc white, contains: barium sulphate, 67 per cent; zinc oxide, 8 per cent.; zinc sulphide, 25 per cent.

†Rosin oil is best determined in a mixture of saponifiable and non-saponifiable oils, by the method of Twitchell. Consult *Journal of Analytical Chemistry*, 5, 379.

‡For comparison of the different methods for determining the carbonic acid in paints, consult "The Determination of Carbonic Acid in White Lead," by F. C. A. Meisel, *The School of Mines Quarterly*, 14, 318.

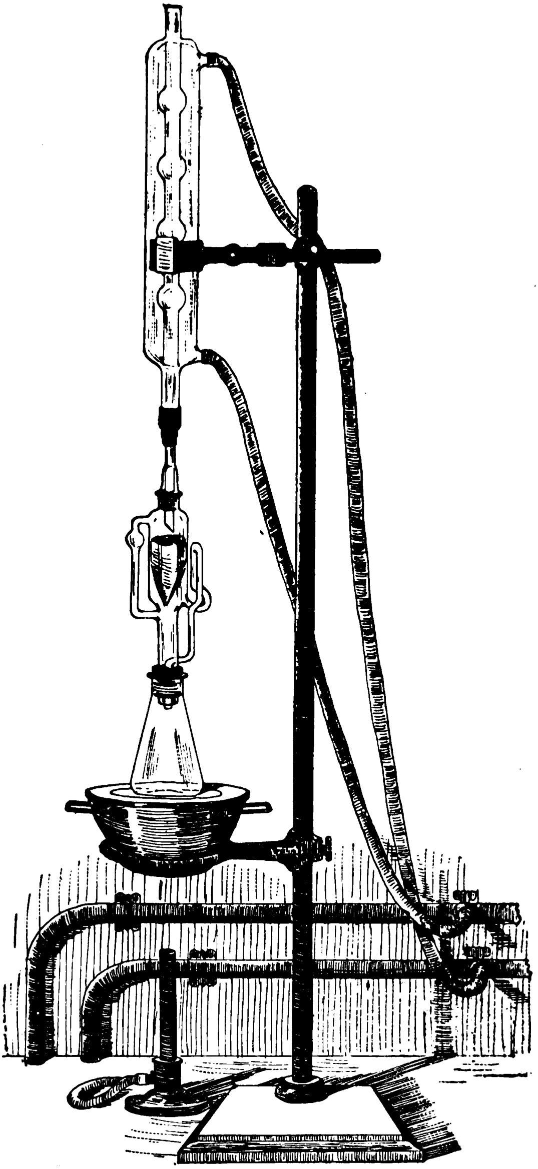

FIG. 1.

water, decanting and filtering each time, and evaporate the filtrate in a platinum dish to dryness on a water-bath.

ANALYSIS OF MIXED CHROMATE, SULPHATE AND CARBONATE OF LEAD.

(Lead Chrome, and White Lead.)

Analysis made same as in Scheme for Lemon Chrome; excess of lead is to be calculated to white lead, $2PbCO_3+PbH_2O_2$.

ANALYSIS OF RED CHROMATE OF LEAD.*

For the lead determination take one gram in a covered casserole, add twenty-five cc. concentrated nitric acid, heat to boiling, and *while boiling* add half a dozen drops, one at a time, of alcohol, by means of a pipette; boil a while longer, add water, and all of the chromate, if it is pure, will be found in solution.

Without this alcohol treatment great difficulty will be experienced in getting the chromate into solution; with it, it becomes very easy. Add twenty-five cc. concentrated sulphuric acid, evaporate to white fumes and complete the analysis as described. For chromium and sulphur trioxide determinations, boil off alcohol and proceed as previously directed.

Chrome greens, in which the coloring mutter is Cr_2O_3, is seldom found in the market pure. Usually it contains from twenty per cent. to seventy-five per cent. of barium sulphate.

As an example of a specification for a compound chrome paint, the following is given:

PENNSYLVANIA RAILROAD COMPANY. MOTIVE POWER DEPARTMENT.

Specifications for Cabin Car Color.

The standard cabin car color is the pigment known as scarlet lead chromate. It is always purchased dry. The material desired under this specification is the basic chromate of lead ($PbCrO_4PbO$), rendered brilliant by treatment with sulphuric acid and as free as possible from all other substances.

The theoretical composition of basic lead chromate is nearly 59.2 per cent. of the normal lead chromate, and 40.8 per cent. of lead oxide, but in the commercial article it is found that a portion of the sulphuric acid added to brighten the color remains in combination apparently with the normal lead chromate, slightly increasing the percentage of this constituent.

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* Known by different names, as scarlet, dark or basic chromate of lead, chrome red, Chinese red, American vermilion and vermilion substitute. Formula: $2\ PbO.CrO_3$ or $PbCrO_4+PbO$.

Samples showing standard shade will be furnished on application, and shipments must not be less brilliant than sample. The comparison of sample from shipment with the standard shade, may be made either dry or by mixing both samples with oil.

Shipments of cabin car color will not be accepted which

1. Contain barytes or any other adulterant.
2. Show on analysis less than fifty-seven per cent. or more than sixty per cent. of normal lead chromate, including the sulphuric acid combined as above stated.
3. Show on analysis less than thirty-eight per cent. or more than forty-two per cent. lead oxide, in addition to the lead oxide in the normal lead chromate.
4. Vary from standard shade.

Office of Gen. Supt. of Motive Power, Altoona, Pa., Feb. 18th, 1891.

The various red paints, Indian red, Tuscan red, and other iron oxides, etc., used in general practice are rarely pure, but contain added amounts of finely pulverized gypsum and calcium carbonate. These oxides, when properly ground and mixed with linseed oil, form paints that cannot be excelled for durability, permanence of color, and cheapness. Many of the mixtures contain varying amounts of japans, but as the japans have been subject to great sophistications of late years, specifications now generally call for linseed oil, turpentine and pigment only.

Thus, two varieties of paints might be roughly classified as: (1) Paints for wood work, and (2) paints for iron work.

The following specifications refer to Class 1:

PENNSYLVANIA RAILROAD COMPANY. MOTIVE POWER DEPARTMENT.

Specifications for Freight Car Color.

Freight car color will be bought in the paste form, and the paste must contain nothing but oil, pigment and moisture.

The proportions of oil and pigment must be nearly as possible as follows:

Pigment seventy-five per cent. by weight.

Oil twenty-five per cent. by weight.

The oil must be pure raw linseed oil, well clarified by settling and age. New process oil is preferred. The pigment desired contains not over one-half per cent. of hygroscopic moisture, and has the following composition:

Sesquioxide of iron, fifty per cent. by weight.

Fully hydrated calcium sulphate or gypsum, forty five per cent. by weight.

Calcium carbonate, five per cent. by weight.

Samples of standard pigment showing shade will be furnished, and shipments will be required to conform with the standard.

The shade of paint being affected by the grinding, the Pennsylvania Railroad standard shade is that given by the dry sample sent, mixed with the proper amount of oil and ground, or better rubbed up in a small mortar with pestle until the paste will pass Pennsylvania Railroad test for fine grinding. It is best to use fresh samples of the dry pigment for each day's testing. The comparison should always be made with the fresh material, and never with the paint after it has become dry. The comparison is easiest made by putting a small hillock of the standard paste and of that to be compared near each other on glass, and then laying another piece of glass on the two hillocks, and pressing them together until the two samples unite. The line where the two samples unite is clearly marked if they are not the same shade. The paste must be so finely ground that when a sample of it is mixed with half its weight of pure raw linseed oil, and a small amount of the mixture placed on a piece of dry glass, there will be no separation of the oil from the pigment for at least half an hour. The temperature affects this test, and it should always be made at 70° F. The sample under test runs down the glass in a narrow stream when it is placed vertical, and it is sufficient if the oil and pigment do not separate for an inch down from the top of the test.

Shipments will not be accepted which

1. Contain less than twenty-three per cent. or more than twenty-seven per cent. of oil.

2. Contain more than two per cent. of volatile matter, the oil being dried at 250° F., and the pigment dried in air not saturated with moisture at from 60° to 90° F.

3. Contain impure or boiled linseed oil.

4. Contain in the pigment calcium sulphate not fully hydrated, less than forty per cent. of sesquioxide of iron, less than two per cent. or more than five per cent. calcium carbonate, or have present any barytes, aniline colors, lakes, or any other organic coloring matter, or any caustic substances, or any makeweight or inert material which is less opaque than calcium sulphate.

5. Varying from shade.

6. Are not ground finely enough.

7. Are a "liver" or so stiff when received that they will not readily mix for spreading.

Altoona, Pa., Office Supt. Motive Power.

As an example of the composition of a paint for iron surfaces (Class 2) the following mixture as used for painting the structure of the elevated railroads in New York City is given:

Boiled linseed oil, ...	9	parts.
Turpentine, ...	1	"
Red oxide of iron finely ground, ...	7½	"

In mixing paints for iron surfaces it is of the first importance that the best materials only be used. Linseed oil is the best medium, when free from admixture with turpentine.

The large percentage of linolein formed in drying, makes the surface of the paint solid and of a resinous appearance, possessing toughness and elasticity. Linseed oil does not crack or blister, by reason of the expansion and contraction of the iron with variation of temperature. Another important characteristic is its expansion while drying, which adapts it to iron surfaces.* The Metropolitan Elevated Railway Company experimented very thoroughly with the various kinds and colors of paints; their labors at last culminated in the selection of a metallic paint for the first coat (formula given above) and a white lead paint for the second and last color, both paints to contain the best linseed oil and enough turpentine to make the paints cover well and facilitate their drying.

The formula of the white lead paint as used is here given:

WHITE LEAD PAINT. OLIVE COLOR.

147.42	kilograms	white lead.
79.38	"	" lime ($CaSO_4$).
34.02	"	French ochre.
1.36	"	Prussian blue.
0.45	"	burnt umber.
79.50	liters	boiled linseed oil.
5.67	"	turpentine.
3.79	"	liquid dryer (boiled linseed oil and lead oxide).

Some engineers prefer red lead instead of iron oxide as the pigment for paints to be used for iron structures.

G. Bouscaren, C. E., states with regard to the painting of bridges, that having used both varieties of paint, he gives preference to the red lead.†

The red lead paint adheres better to the iron and fails principally by wear and a gradual transformation of the red lead into carbonate, whilst the iron paint fails by scaling.

ASPHALT PAINT.

Until within recent years little has been known in this country of the valuable properties of the asphalt. In the popular mind it is often confused with certain coal-tar products, which, though similar in appearance, differ essentially from asphalt in character. Asphalt oils are of a nearly non-volatile nature, and are therefore permanent, while on the other hand, coal-tar is volatile.

The so-called asphalt paints which have been used in the past are such only in name. They contain, at best, but a very small per cent.

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* On the Construction of the Second Avenue Line of the Metropolitan Elevated Railway of New York. By G. Thomas Hall, C. E., *Trans. Amer. Soc. Civil Eng.* 10, 130.

† *Trans. Amer. Soc. Civil Engineers*, 15, 429.

of asphalt, which is incorporated in the form of a pigment and which serves no valuable purpose. Asphalt, on the contrary, should be the main constituent, since the value of such a paint depends upon the presence of the permanent asphalt oils.*

FIRE-PROOF PAINTS, SILICATE PAINTS, ASBESTOS PAINTS, ETC.

The principle of action of these paints is not to render wood-work or similar material fireproof, but to retard combustion.

Wood treated with a solution of zinc chloride, or with a solution of sodium silicate, can be rendered nearly non-inflammable, and after such treatment and drying, paint can be applied.

Instead of using the ordinary paints for this purpose, various compounds are incorporated in the paint itself to render the latter non-inflammable. Thus the preparation of Professor Abel J. Martin, of Paris, is as follows:

Boracic acid, borax, soluble cream of tartar, ammonium sulphate, potassium oxalate, and glycerine mixed with glue and incorporated with a paint. It is the result obtained after long experiments in response to a prize of 1,000 francs, offered by the Society for the Advancement of National Industry of France. A committee consisting of Professors Dumas, Palaird, and Troost, after testing the materials, consisting of painted woods and various fabrics, for seven months, reported in favor of this preparation. The municipality of Paris made its use obligatory in all of the theatres there, and it has stood the test of the last six years.

BLUE PIGMENTS.

Ultramarine being a silicate, can be analyzed by fusion methods for silicates. This applies also to cobalt blue.

COMPOSITION OF ULTRAMARINE.

SiO_3,	49.68	per cent.
Al_2O_3,	23.00	"
S,	9.23	"
SO_3,	2.46	"
Na_2O,	12.50	"
H_2O,	3.13	"
Total,	100.00	"

**Am. Eng. and R. R. Journal*, 65, 185.

COMPOSITION OF COMMERCIAL PRUSSIAN BLUE.

Al_2O_3,	2.45	per cent.
Fe_2O_3,	3.31	"
$CaSO_4+SiO_2$,	89.86	"
$CN+S$,	4.11	"
H_2O,	0.27	"
Total,	100.00	"

COMPOSITION OF SMALTS.

SiO_2,	56.4	per cent.
Al_2O_3,	3.5	"
Fe_2O_3,	4.1	"
CoO,	16.0	"
CaO,	1.6	"
K_2O,	13.2	"
PbO,	4.7	"
Total,	99.5	"

EXAMINATION OF THE OIL AFTER EXTRACTION FROM THE PAINT.

The only adulterants used in linseed oil, in this connection, are mineral oil and rosin oil.

Turpentine, when present, is not an adulterant, and a mixture, extracted from a paint, may contain linseed oil, mineral oil, rosin oil, turpentine, and rosin spirit.* The latter is quite distinct from rosin oil, and when properly prepared is a perfect substitute for turpentine. If the liquid extracted from the paint is a mixture of linseed oil, turpentine, and rosin spirit, the determination of the amounts of each is somewhat difficult.

Turpentine can be distinguished and determined in the presence of rosin spirit by the action of the former on polarized light, rosin spirit being inert, thus: The specific rotation of American turpentine varies between +8.8 to +21.5. The bromine absorption is also an indication.

The bromine absorption of turpentine varies between 203 to 236.

The bromine absorption of rosin spirit varies between 184 to 203.

The determination of the amounts of petroleum naphtha and

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*Coal tar naphtha has an extended use in the preparation of varnishes; the use of it in paints, however, is very limited.

SCHEME FOR THE ANALYSIS OF MIXED CHROMATE AND SULPHATE OF LEAD (LEMON CHROME*) NOT GROUND IN THE OIL.

Pulverize the sample, pass through a 100-mesh sieve and mix. To one gram in a small beaker, add hydrochloric acid and heat. Any insoluble matter (usually barytes as a gross adulteration) is to be filtered out, washed, ignited, and weighed.

LEAD.—One gram is treated in a covered casserole with twenty-five cc. concentrated sulphuric acid and heated moderately until the residue is perfectly white; cool, dilute with fifty cc. water and again cool; add fifty to seventy-five cc. of ninety-four per cent. alcohol, stir, and allow to stand one hour. Filter, wash well with alcohol.

CHROMIUM AND SULPHURIC ACID (SO_3).—Treat one gram with about twenty-five cc. concentrated hydrochloric acid, boil, dilute to 100 cc. and while hot add excess of ammonium hydroxide, which precipitates the chromium and the greater part of the lead. Boil off the excess of ammonia, filter and wash *carefully* with hot water.

<table>
<tr><td colspan="2">1. PRECIPITATE FOR Cr.—Dissolve in dilute HCl, neutralized excess of acid with NH_4OH, precipitate Pb with H_2S gas and filter into a <i>porcelain dish.</i></td><td rowspan="2">2. FILTRATE FOR SO_3.—Acidify with HCl, concentrate, add boiling solution of $BaCl_2$ drop by drop and determine SO_3 as usual.</td></tr>
<tr><td>3. PRECIPITATE.—PbS, reject.</td><td>4. FILTRATE.—Boil off every trace of H_2S and precipitate Cr with NH_4OH in the usual manner. Put the moist precipitate and filter paper into a crucible and ignite carefully. Weigh as Cr_2O_3.</td></tr>
</table>

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*Analysis of Chrome Paints. By W. L. Brown, *J. Anal. Chem.*, 1, 213–215.

ANALYSIS OF CHROME GREEN.

(Composed of Yellow Chromate of Lead, Prussian Blue and Lead Sulphate.)

To one gram of sample add twenty-five cc. HCl, heat to boiling several minutes, add water, allow to stand ten minutes, then filter and wash thoroughly with hot water.

<table>
<tr>
<td rowspan="3">1. RESIDUE.—Prussian blue (plus barytes or other insoluble matter, if present). Dry and ignite to Fe_2O_3.
Weight multiplied by 2.21 equals per cent. Prussian blue.</td>
<td colspan="3">2. FILTRATE.—Nearly neutralize with NH_4OH, leaving, however, the solution slightly acid. Pass H_2S gas through till Pb is all precipitated. Filter and wash.</td>
</tr>
<tr>
<td rowspan="2">3. PRECIPITATE, PbS.—Dissolve on filter with hot dilute HNO_3 and boil the solution. Filter from collected S and bring filtrate of $Pb(NO_3)_2$ to small bulk, with several additions of H_2SO_4. Evaporate to fumes of SO_{31}, cool, add water and alcohol, filter, wash and weigh as $PbSO^4$.</td>
<td colspan="2">4. FILTRATE.—For Cr (and Fe), boil off H_2S, add NH_4OH, in slight excess, boil this off and wash the $Cr_3(OH)_6$ (and $Fe_2(OH)_6$), as customary. Weigh precipitate as $Cr_2O_3+Fe_2O_3$. After the weight is obtained, mix with one part KNO_3 and three parts Na_2CO_3; fuse in platinum crucible to clear fusion, cool, boil with water, filter and wash.</td>
</tr>
<tr>
<td>5. RESIDUE.—Filter, wash, dry, and weigh as Fe_2O_3, if it is wanted as a check.</td>
<td>6. FILTRATE, for Cr.—Precipitate with NH_4OH in glazed porcelain dish. If the weight of Cr_2O_3 is *very nearly* the same as before, then there has been no Fe extracted from the Prussian blue by the acid treatment. Some varieties are affected by this, others not. If the weight is less than the original, deduct it from same. The result is Fe_2O_3, which is also to be calculated to Prussian blue and added to the other.</td>
</tr>
</table>

turpentine in a mixture can be made by the method of H. E. Armstrong, *J. Soc. Chem. Ind.*, 1, 480; consult also Allen, Com. Org. Anal., 2, 48–50.

References: "How to Design a Paint." By C. B. Dudley, *Railway and Eng. J.*, **65**, 174, 318.

"On the Analysis of White Paint." By G. W. Thompson, *J. Soc. Chem. Ind.*, **15**, 432.

"Detection of Rosin and Rosin Oil in Oils and Varnishes." By F. Ulzer, *Ibid.*, **15**, 382.

"Technical Analysis of Asphaltum." By L. A. Linton, *J. Am. Chem. Soc.*, **16**, 809.

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"Preservative Coatings for Iron Work." By A. H. Sabin and A. O. Powell, *Engineering News*, Feb. 5, 1895, p. 86.

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TO OUR READERS.

We are often called upon to select and recommend engineers and chemists to fill positions in testing chemical and engineering laboratories. In view of this a space will be devoted to this subject under the head of Professional Wants, free of charge. All communications address to Office of DIGEST OF PHYSICAL TESTS, 1424 North Ninth Street, Philadelphia, Pa.

PROFESSIONAL WANTS.

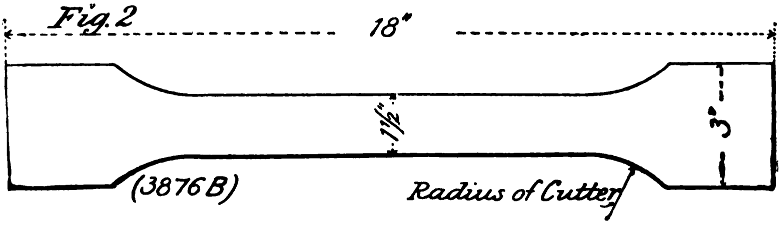
ENGINEER OF TESTS.—Position wanted with large company by metallurgist having works and college training. Address DIGEST OF PHYSICAL TESTS.

WHAT is said to be the largest chain ever made has been forged at the Tipton Green Chain Works for the British Admiralty. It is a sling chain, close-linked, of 3 13-16 iron, and side welded. There is no testing machine strong enough to break it, but it is to be tested to about 400 tons. It is to be used for lifting ingots and armor plates.

MILLING MACHINE FOR TEST SPECIMENS.

WE illustrate on page 129 a special milling machine built by the well-known Testing Machine Company of Riehlé Brothers, Philadelphia, Pa., U. S. A., to meet the demands of rolling mills, railway shops, boiler-makers, bridge-builders, etc., for the rapid and accurate preparation of test specimens. The cutters are of the spiral type, being 6 in. in diameter and 12 in. long. They are arranged with their axes vertical and driven from each end. The prime driver is a bronze worm gear under each head carrying cutters, driven by one worm-shaft of cast or tool steel. The worms are right and left, so that the thrust is self-contained. The specimen carriage slides at right angles to the bed similarly to the cross-slide of a lathe. In it are placed specimens 18 in. long by 3 in. wide, roughly sheared. A clamp bar hinged to the carriage is brought into position and secured by a pin on the free end. In this bar are two clamping screws, which are screwed down upon the specimens to hold them rigidly in position. The heads carrying cutters are connected by right and left screws, and can be brought together or separated by moving a lever at the front of the machine. In working, the cutters are fed inwards to the width required for the specimen; the cross-feed is then thrown in, and when the desired length is reached, the feed is automatically tripped. The whole machine is built in a manner to resist with no appreciable vibration the very severe duty it has to perform. Twenty-four specimens of steel ½ in. thick (similar to that shown above, Fig. 2) were milled from 3 in. to 1½ in. wide in 25 minutes. They were perfectly parallel, and had a surface that required no further finishing. The machine was designed by Mr. Joseph W. Bramwell, superintendent of the Riehlé Brothers Testing Machine Company.—*Engineering, February 26th, 1897.*

Fig. 2



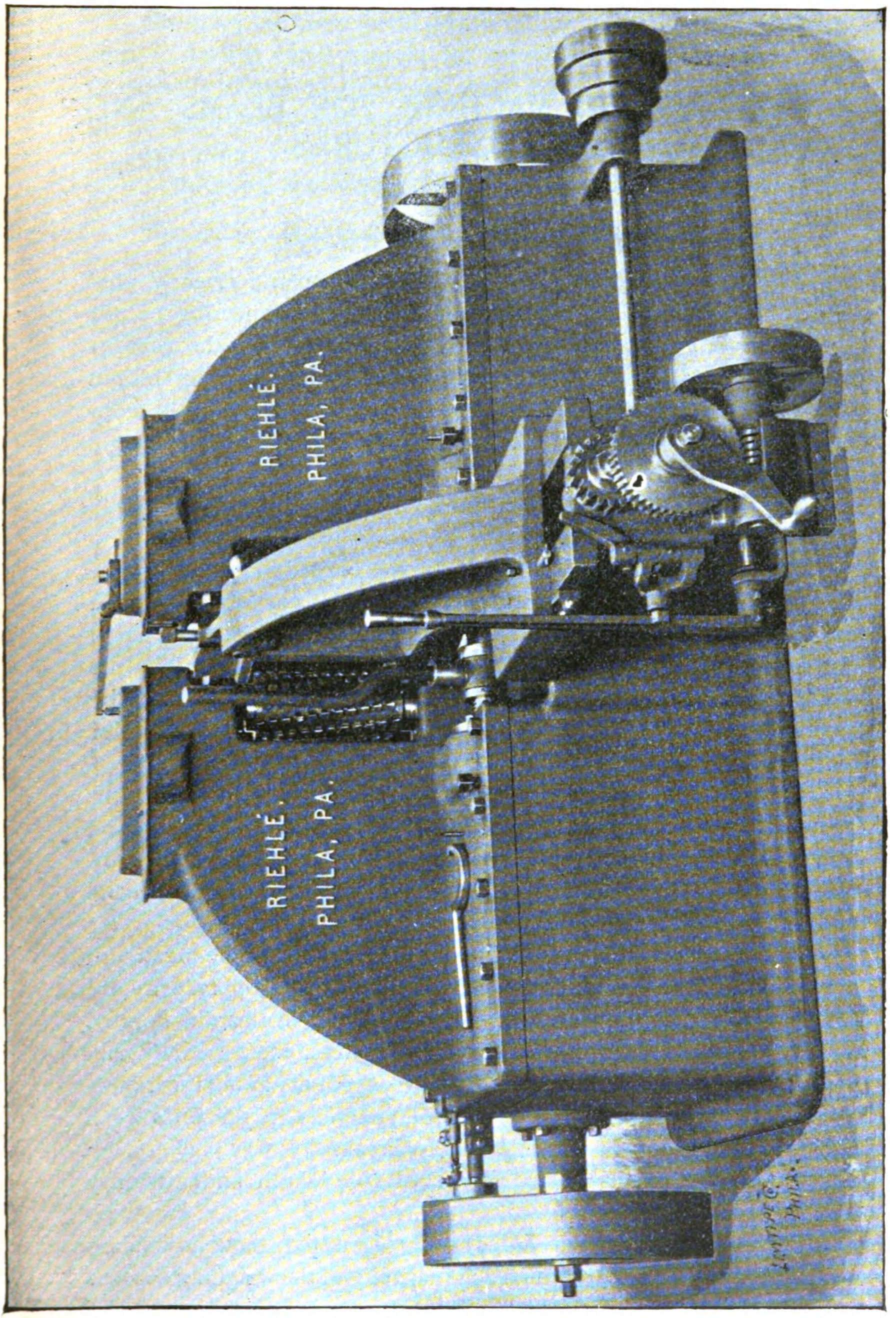


Fig. 1.—Test Piece Milling Machine.

Constructed by Messrs. Riehlé Brothers, Engineers, Philadelphia.

A NEW TESTING MACHINE FOR BEAMS AND FRAMED STRUCTURES.

(Capacity 50 tons.)

By Malverd A. Howe, Terre Haute, Ind.

A BRIEF description of a new testing machine recently constructed for the Department of Civil Engineering of the Rose Polytechnic Institute may be of interest, as the machine is unique in many ways. The design of the machine was worked out in the Civil Engineering Department of the Institute, and the construction placed where the best work for the money expended could be obtained.

The general construction of the machine is clearly shown by the accompanying illustrations.

The weighing device was made by the United States Scale Co., of Terre Haute. Stock patterns were employed for all levers with the exception of two which were quite simple. The wooden frame was finished to dimensions and bored for all bolts, rods, etc., by the Terre Haute Car & Manufacturing Co., of Terre Haute. The foundation was put in place by a local contractor and the remainder of the materials and labor was furnished by the Institute shops.

In designing the machine particular attention was paid to simplicity of details, the sizes and shapes of specimens which could be tested, the adjustability of the various parts to suit various sizes of specimens, and the probable accuracy of the results obtained with the machine as a whole.

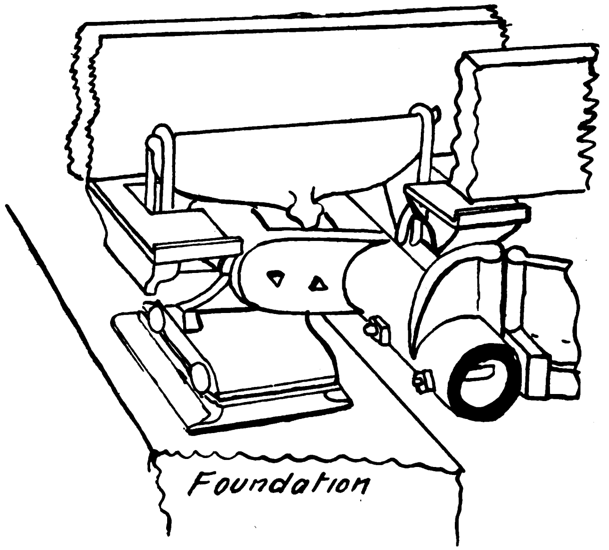
The drawings show the simplicity of the details. The maximum dimensions of the frame which the machine will easily take in are twenty feet in length, five feet in width, and six feet in height, making it possible to test various joints, splices, etc., used in carpentry, small trusses, all classes of floors in wood, metal or stone, and, in short, practically, any combination of materials in the form of a frame which fifty tons would be likely to break.

Cross-breaking specimens can be of any length under twenty feet.

Columns up to six feet in length can be tested, though the sizes must necessarily be small, owing to the capacity of the weighing device.

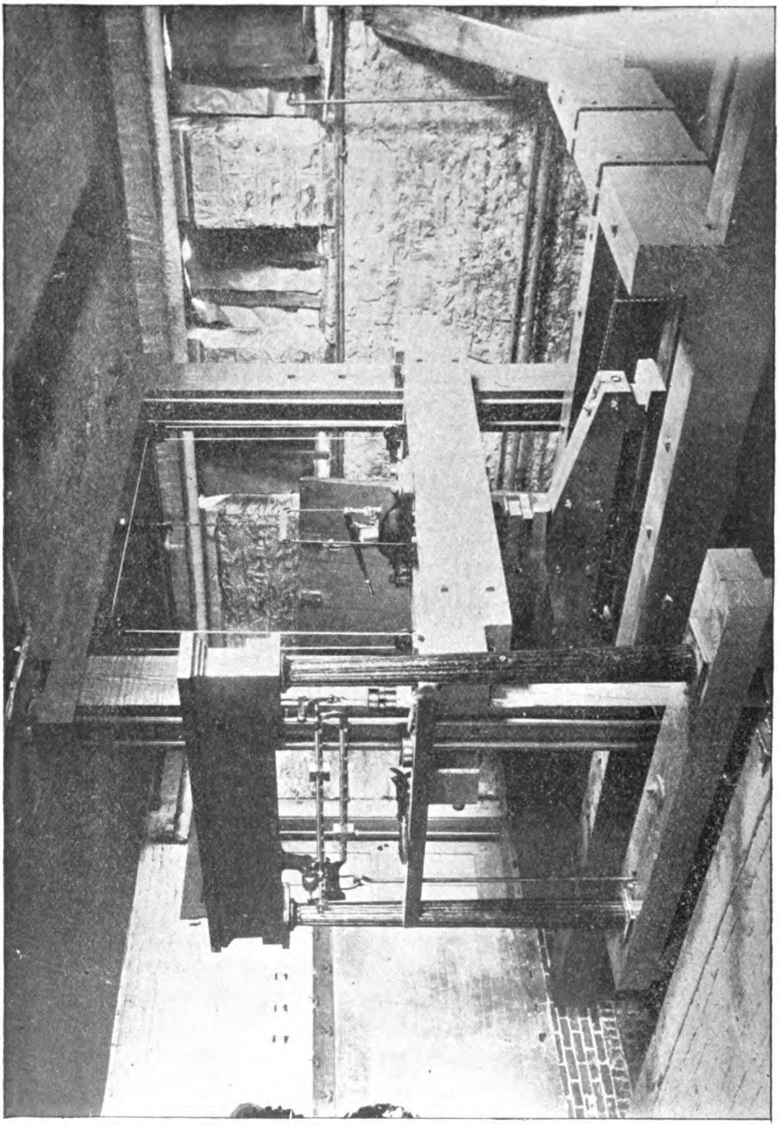
Probably the more novel details of the machine are the devices used in testing large timbers for cross-breaking strengths. These devices are shown in detail on sheet No. 6, page 134, and may be briefly described as follows:

Each end of the specimen is supported in a double stirrup which is so constructed that there is perfect freedom of motion laterally and longitudinally. The stirrups which directly support the specimen are hung on knife-edges which are horizontal and perpendicular to the longitudinal axis of the beam. By proper adjustments the line of these knife-edges may be brought into the *neutral plane* of the specimen.



Sketch showing Hangers etc.

This arrangement has the particular advantages that when the knife-edges are brought into the neutral plane of the specimen, the



Fifty-ton Testing Machine for Beams and Framed Structures.

points where the reactions cut the neutral plane will remain at a constant distance apart, thereby making the *span constant;* and, furthermore, owing to the free motion of the stirrups about the knife-edges in the neutral plane practically no longitudinal stresses in the specimen are induced by the supports.

It is believed that this is the first device by means of which the end knife-edges may be placed in the neutral plane of the specimen, thereby enabling the experimenter to obtain a constant span and to eliminate longitudinal stresses caused by the supports.

This method was first used by Professor T. Gray in testing small specimens. The loading is applied to the specimen through the medium of a straining beam which has at equal distances on each side of its centre a knife-edge firmly fixed to an iron plate. The load is applied midway between these knife-edges which remain a fixed distance apart. On the specimen, symmetrical about its centre, are placed two flat bars of iron upon each of which is a steel roller with a flat V milled out very nearly to its centre in which the knife-edges of the straining beam lie.

This arrangement assures the application of two equal and symmetrical loads, for, as the specimen bends under the loading, the rollers move upon the plates under them and accommodate themselves to the new conditions.

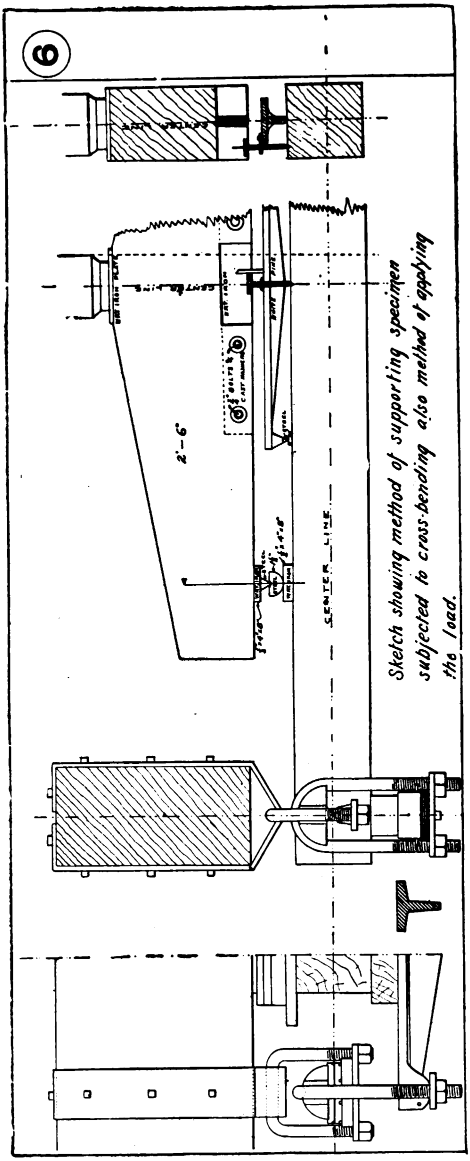
All longitudinal stresses due to fixed knife-edges are eliminated by the rollers.

Since the knife-edges are fixed and lie in rollers resting on top of the beam, as the specimen distorts the points in the neutral plane where the two loads, transmitted by the rollers, cut the same will vary a little in their distance apart, but not enough to appreciably affect the results.

(Eventually these two symmetrical loads will be applied by means of adjustable stirrups with knife-edges which may be placed in the neutral plane of the piece.)

The advantage of applying two equal and symmetrical loads to the specimen cannot be overestimated if a fair idea of the strength of the beam is desired.

Between the loaded knife-edges the *bending moment is constant and the shears equal zero,* hence for this distance the fibers of the specimen are subjected to the same stresses end to end respectively. As a result the beam will fail at the weakest section which lies between the two loadings. In other words, a comparatively large portion of the specimen is subjected to precisely the same stresses and consequently a fair idea of the general details of the true strength of the beam is obtained.



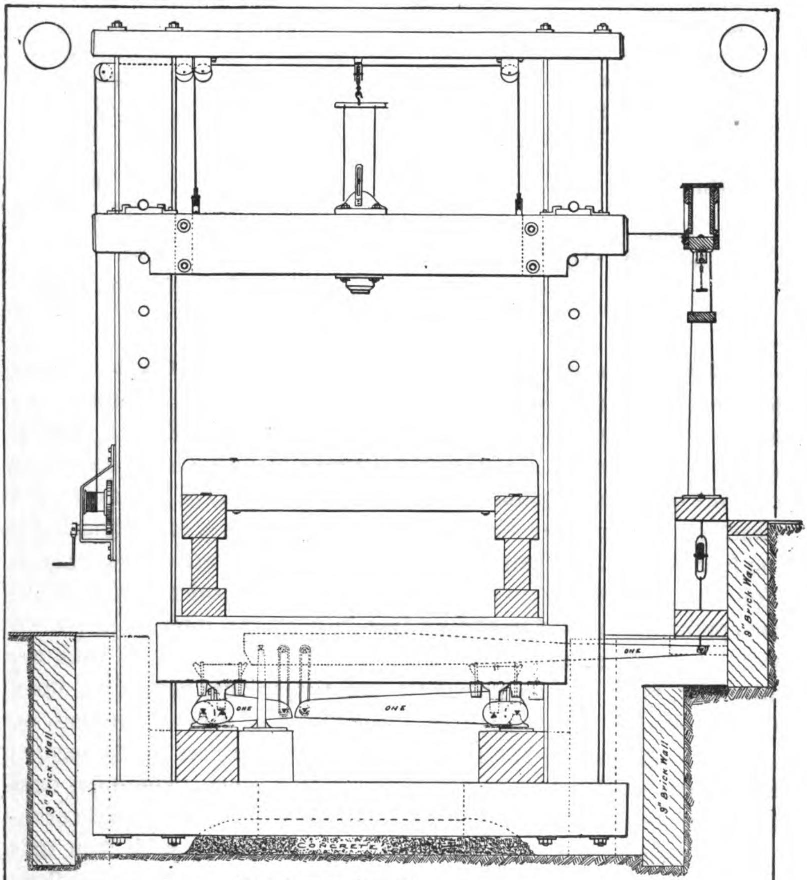
Sketch showing method of supporting specimen subjected to cross-bending also method of applying the load.

The ordinary method of supporting the specimen upon fixed knife-edges induces longitudinal stresses and a change in the length of span specimen as the beam distorts. The usual custom of applying the entire loading at the centre of the beam causes a maximum bending moment at one point—namely, under the loading—and consequently unless the specimen has exceptionally weak actions elsewhere it will fail at the centre, and this is further the result of the cutting of the fibers by the plate through which the loading is transmitted to the beam. Evidently the ordinary method does not give the specimen a fair trial.

Experiments show that the above statements are correct.

The two-load method is exceptionally well adapted for the determination of moduli of elasticity as the central portion of the specimen is free of apparatus and the deflections can be readily and accurately measured by means of a micrometer screw and electric contact. The general details of the device employed with this machine is shown on sheet No. 6, page 134. The micrometer screw reads directly to thousandths of an inch.

The sensibility of the weighing device is very good. The weight of the levers, platform, and large straining beams is about five tons: an addition of two pounds shows quickly at the weighing lever. With a specimen in the machine and loaded with twenty tons, an addition of ten pounds causes the weighing lever to change position.



END VIEW AND SECTION

As the machine is designed an ordinary screw or hydraulic jack can be employed in applying pressure to the specimens. At present this machine is fitted with a hydraulic press having a capacity of twenty-five tons, which cost $197 three years ago.

The actual cost of the machine is given below by items, and is interesting in showing how much can sometimes be accomplished with the expenditure of a little money.

Metals, such as bolts, rods, etc.,	$64 99
Timber—dimensioned and bored (white oak),	80 39
Weighing device in place,	200 00
Foundation in place,	47 25
Labor from Institute shops,	63 25
Outside labor,	14 75
Painting,	6 75
Total,	$477 38

June 24th, 1896.
MALVERD A. HOWE,
Terre Haute, Ind.

CONVERSION OF EMERY INTO CORUNDUM.—Mr. Hasslacher has patented an electric process of converting emery into corundum by means of the arc of alternating currents, says the *Trades Journal Review*. As heat and not decomposition is aimed at, continuous currents would be unsuitable. The furnace is made of firebricks and stands on two bridges; the hollow underneath serves as receptacle for the fused mass, there being a small hole in the bottom of the furnace. This hole is covered with a glass plate. The electrodes (carbon rods) are approached to within one or two inches; the interval is packed with lumps of carbon. The emery, also the finest dust of little use otherwise, is mixed with powdered coal, the amount depending upon the iron oxide in the emery; for 25 per cent. of oxide 5 per cent. of carbon is reckoned. The coal lumps are soon burned by the oxygen of the iron oxide and the arc forms under hissing. The inner mass begins to melt, the glass plate give way, and a stream of fused corundum flows out. The hard outer crust is then broken with iron rods and new material thus fed to the arc. This addition stops the flow, which starts again after ten or fifteen minutes. The base-plate is strewn with fine emery powder to protect it from the intense heat of the fused mass. The resulting corundum is almost free of water, of which the emery contains about 5 per cent. It is crystalline, colorless, and then resembling quartz, pink or blue; fine, small crystals of sapphires are found in druses. The current is kept at 250 amperes and 40 or 60 volts.

A HYDRAULIC DYNAMOMETER.*

PROF. JAMES D. HOFFMAN, of the Mechanical Department of Purdue University, has constructed a hydraulic dynamometer with which he has made a series of tests on the application of cutting edges to iron and steel, the dynamometer being used to measure the work done under various conditions.

This machine was constructed at Purdue University in the winter of 1894 and has been in use since September, 1895, giving some very valuable results. It was used by the Master Car Builders' Committee on laboratory tests of brake shoes in determining the relative hardness of different grades of cast iron and steel used.

Figs. 1, 2, and 3 show the main features of the dynamometer. This machine consists essentially of a hollow shaft, mounted in suitable bearings carried by the framework, which in turn carries three pulleys, *A*, *B*, and *C* (Fig. 2), and a casting to which two cylinders are fastened by means of a double yoke and trunnions. These cylinders *E*, *E* (Fig. 2), are diametrically opposite each other, are exactly of the same size, and similarly placed with reference to the shaft, so that the balance is maintained. The pistons, working within the cylinders, are connected by ball and socket joints, the links which are fastened to projections on the loose pulley *A*, thus allowing the cylinders a slight vibratory motion on the trunnions.

A brass tube connects the interior of each cylinder with the opening in the shaft. To allow for the slight motion of the cylinder a ground joint is made in this connection at *a* (Fig. 2).

As shown in Fig. 3, the shaft is hollow throughout its entire length. At one end is fastened a casting *b* provided with a small piston working against a spring; to this piston is attached the recording pencil. This casting being connected to the shaft, turns with it, but the piston is kept from turning by means of the frame which carries the recording pencil.

At the opposite end of the shaft is attached a pressure gauge and oil-pump *H* (Fig. 2). There is also a stuffing box at this end, allowing the oil in the shaft to lubricate the bearing and still preventing its escape. By means of the pump the hollow shaft cylinders and pipe connections are filled with oil, and in case of leakage it is used to replace what is lost.

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* From the *Railroad Gazette.*

Pulley *A*, shown in Fig. 2, is loose on the shaft except for its connection by means of the pistons already described. This pulley carries the belt driving the dynamometer. Pulley *B* is loose on the shaft, and carries the driving belt when the dynamometer is not in use, while pulley *C* is fixed to the shaft and from it is run the machine to be tested.

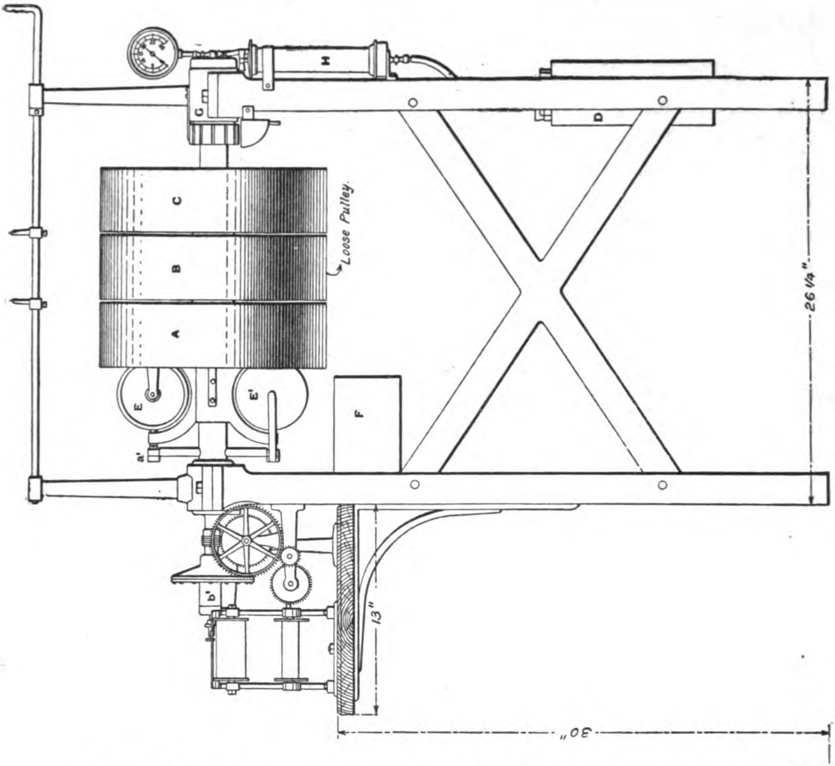


FIG. 2.

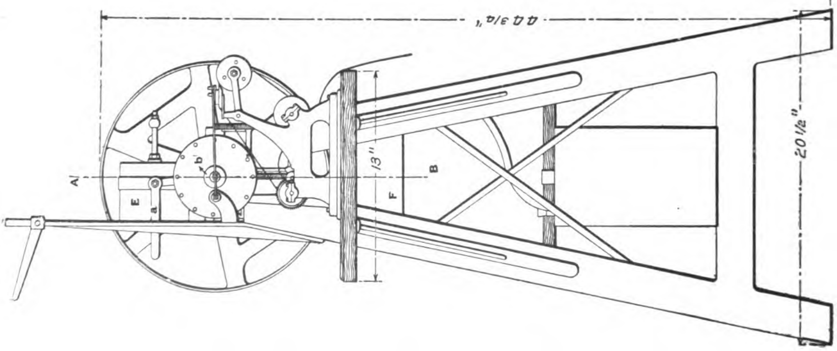
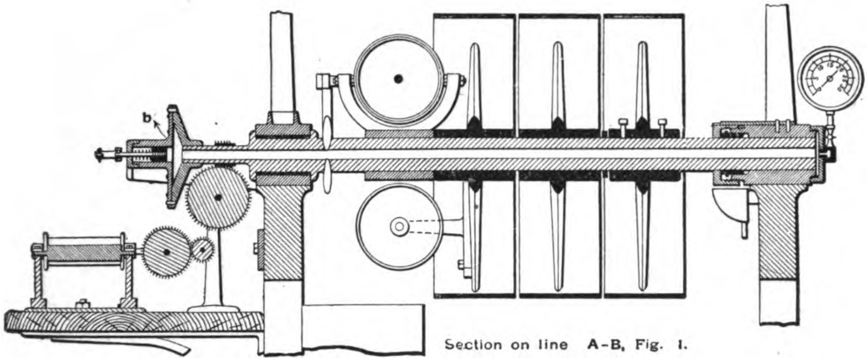


FIG. 1.

The action of the dynamometer is as follows: The pull of the belt on pulley *A* is transmitted through the links to the pistons. This produces a pressure on the oil in the cylinders and shaft, which pressure is transmitted without loss to the piston operating the recording pencil, and is also shown by the pressure gauge. As the cylinders are connected to the shaft, it is made to rotate with pulley *A*, along with pulley *C*, which drives the machine being tested.

It is evident that the pressure of the oil is dependent upon the resistance to turning offered by the pulley *C*, and that any variation in this resistance will be shown immediately by the gauge and recording pencil.

Figs. 1, 2, 3, and 4 show the arrangement of the recording apparatus. The machine is self-registering. The recording pencil consists of a bronze point attached to the piston, *f v*, by means of a series of arms, so that a true straight-line motion is produced. The record is traced on metallic-surfaced paper carried by a drum, which is driven by gearing from the shaft. The speed of the drum can be varied by a system of interchangeable gears. No cup leathers are used on any of the pistons, and the leakage of oil is very slight and has been found to have no appreciable effect on the results.



Section on line A-B, Fig. 1.

FIG. 3.

The movement of the registering pencil being dependent upon the spring placed back of the recorder piston, before tests could be made it was necessary to calibrate the dynamometer carefully. This was done in two ways.

Fig. 4 shows the machine as fitted for calibration by the first method. The pulley, *A*, was held stationary by means of a wire running to the floor. A lever was attached to the pulley, *C*, so that by applying a load to the lever any desired pressure could be obtained in the cylinder. The pressure gauge attached to the machine was first tested in the laboratory, and was brought to read exact pounds by applying loads to the lever. When at these points the paper was moved, giving lines parallel to the base line, this operation was repeated with a second gauge, and the average of the two sets of readings showed the constant of the spring, and hence the dynamometer to be .344 in., vertical, on the paper, equal to a pressure of 1 lb. per square inch.

As an additional check the second method was used. This made use of a differential arm attached to the pulley *C*, and shown in Fig. 5. Known weights were hung at measured distances along the arm, and the distance from the axis of the shaft to the point of application being known, the turning moment could be determined. The area of each cylinder is 10 sq. in., and the radius of the path described by the centre of the cylinder equals 3.82 in., so that the pressure per square inch could be calculated without reference to the gauge. This method showed the dynamometer constant to be .345 in., as compared to .344 in., as obtained with the gauges.

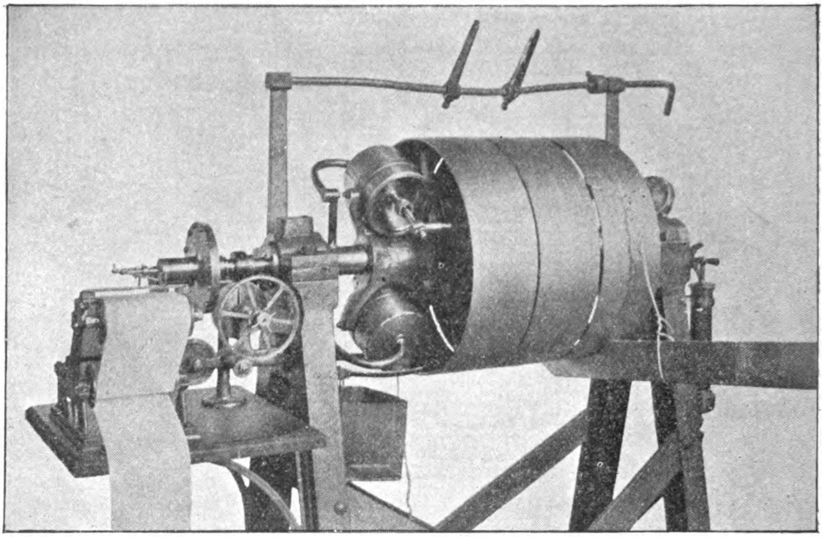


FIG. 4.—HOFFMAN'S HYDRAULIC DYNAMOMETER.

To insure the pencil returning each time to the same line when the load is removed, a constant pressure is put on the spring when the piston *b'*, Fig. 3, is against the stop. A stationary bronze point is set to record this line, and all measurements are taken from it. The zero line is below this base line a distance readily determined when the scale of the spring is known.

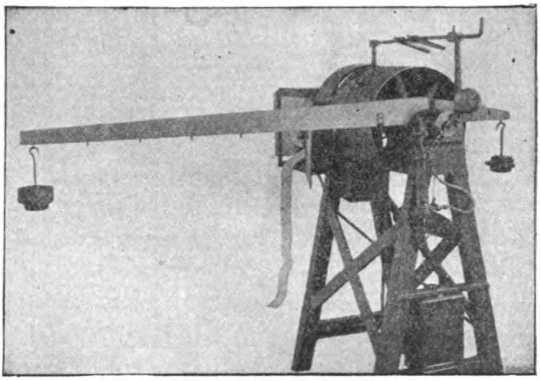


FIG. 5.—HYDRAULIC DYNAMOMETER.

The dynamometer has been found to be possibly more accurate when operated by differences; that is, by taking a card of the machine (lathe or planer) in motion without cutting and a card with the tool in operation. The difference in the height of the cards is evidently due to the action of the tool. If the friction of the machine and work (without cutting action) is not sufficient to move the pencil from the base line under the compression of the spring used, a device for weighting the back gears of the lathe is introduced as shown in Fig. 6.

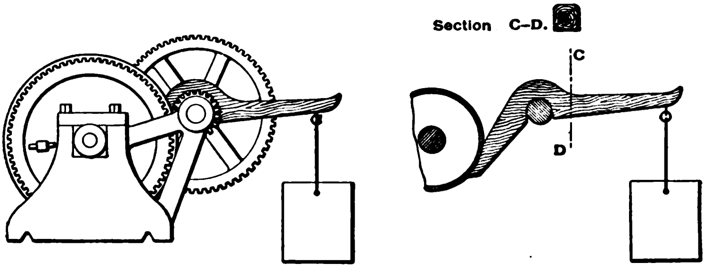
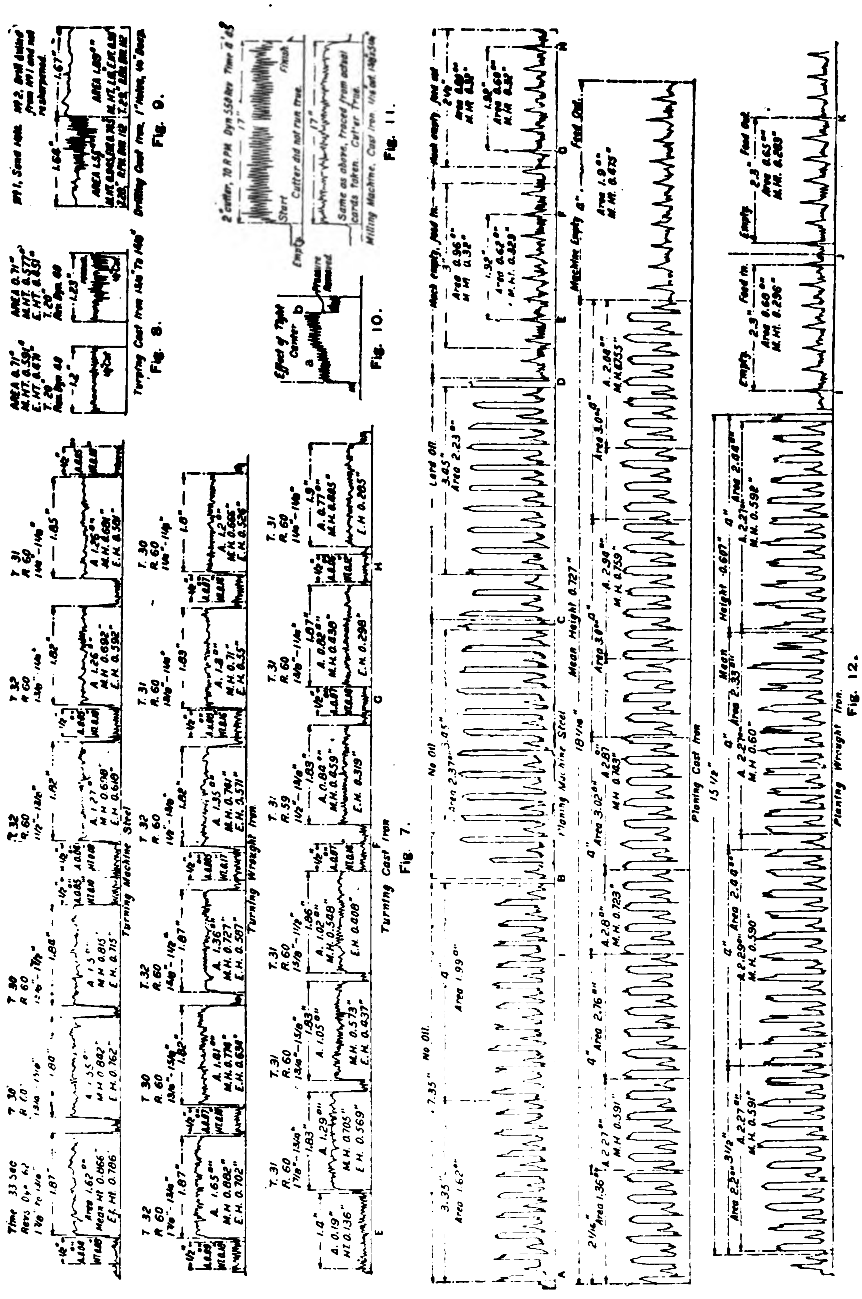


FIG. 6.

A few sample cards are given to show how readily the recording device responds to slight changes in the power transmitted.

Fig. 7 is a reproduction from cards taken from an 18-in. lathe,



SAMPLE CARDS TAKEN FROM HOFFMAN'S HYDRAULIC DYNAMOMETER.

while turning machine steel, wrought iron and cast iron, and shows the gradual reduction in the height of the card as the diameter of the stock decreases, also the relative heights of cards from the different metals. The cards at *F*, *G*, and *H* are friction cards. Figs. 8 and 9 show the effect of sand holes in a casting. The cutting edge of the drill was dulled, as indicated by the increased height of the card after passing the sand hole.

Fig. 10 was taken while turning machine steel. The tail centre proved to be too tight, and from *a* to *b* shows an increase due to the grooving of the centre. At *b* the pressure was removed. Fig. 11 shows a card taken on a milling machine. The upper card shows the effect of running with the cutter out of centre. The lower card shows the same work done with a true cutter.

Fig. 12 illustrates the action on a shaping machine. The change shown between the cards marked *A B* and *B C* is due to increasing the feed. That shown between *B C* and *C D* is due to cutting with and without lard oil, while the difference between *E F* and *G H* is that of the machine running empty, with and without the feed. *I J* and *J K* show a similar effect when planing wrought iron with the feed in and out.

Trials have been made so as to determine the weight of various metals removed per hour and the corresponding horse-power required to drive the machine. In finding the weights of metals removed per hour, the constants .26, .28, and .284 were used as the weights of one cubic inch of cast iron, wrought iron, and steel respectively. The feed was retarded slightly in the harder metals in proportion of 1.48 for cast-iron, 1.45 for wrought iron, and 1.4 for steel, of the travel of the tool in inches per minute.

These tests gave the following as the relations existing between the weight of chips removed per hour and the horse-power used: Horse-power equals .039 W for steel, .0347 W for wrought iron and .021 W for cast iron.

Comparing these results with those of Hartig and Smith, the values of the constant C in the formula H. P. $= C\ W$, are as follows:

	Cast iron.	Wrought iron.	Steel.
Hoffman, ...	.021	.0347	.039
Hartig, ...	.030	.032	.047
Smith, ...	.023	.028	.042

The average pressure at the point of the tool was found to be: Cast iron, 192 lbs.; wrought iron, 337 lbs., and steel, 371 lbs.

NOTES AND COMMENTS.

LITERATURE.

Engineering Chemistry.—A Manual of Quantitative Chemical Analysis for the use of Students, Chemists, and Engineers. By Thomas B. Stillman, M. Sc., Ph. D., Professor of Analytical Chemistry in the Stevens Institute of Technology. Published by Chemical Publishing Company, Easton, Pa. December, 1896. Price, $4.50.

Our readers will welcome this work with considerable pleasure. It is an accumulation of many years' experience in the chemical laboratory, bearing upon subjects closely related to engineering. The following list (together with 154 illustrations) will give some idea of the magnitude and usefulness of the work: Determination of Iron in Iron Wire; Determination of Alumina in Potash Alum; Determination of Copper in Copper-Sulphide; Determination of Sulphur-Trioxide in Crystallized Magnesium Sulphate; Determination of Lead in Galena; Determination of Iron by Sitration with Solution of Potassium Bichromate; Determination of Phosphoric Acid in Calcium Phosphate; Determination of Chronium Trioxide in Potassium Bichromate; Analysis of Limestone; Coal and Coke; Hematite, Limonite, Magnetite, and Spathic Iron Ores; Scheme for Analysis of Blast Furnace Slag; Water to Determine Scale-forming Ingredients; Sanitary Analysis of Water; Composition of Boiler Scale; Water for Locomotive use; Feed Water Heaters, Use of Chemicals, and Filtration and Purification of Boiler Waters; Filter Presses for Rapid Water Filtration; Determination of Heating Power of Coal and Coke; Calorimetry Determination of Sulphur in Steel and Cast Iron; Determination of Silicon in Iron and Steel; Determination of Carbon in Steel; Carbon Compounds of Iron; Determination of Phosphorus in Cast Iron and Steel; Classification of Steel; Determination of Aluminum in Iron and Steel; of Sulphuric-acid and free Sulphur in Trioxide in fuming Nordhausen Oil of Vitriol; of Manganese in Iron and Steel; of Zinc in Ores; Sodium Cyanide as a Component of Potassium Cyanide; Chemical and Physical Examination of Portland Cement; Determination of Nickel in Nickel Steel; Analysis of Chimney Gases for Oxygen, Carbon-Dioxide, Carbon-Monoxide, and Nitrogen;

Analysis of Flue Gases with the Orsat-Müencke Apparatus; Analysis of Coal Gas, Water Gas, Producer Gas, etc., by the Hempel Apparatus; Heating Value of Combustible Gases; Manufacture of Water Gas; Producer Gas; Oil Gas; Natural Gas; Practical Photometry; Liquid Fuel; Analysis of Clay, Kaolin, Fire Sand, Building Stones, etc.; Physical Test of Building Stones, Alloys; Analysis of Tin Plate; Chrome Steel, Soap; Chemical and Physical Examinations of Paper of Petroleum and Lubricating Oil; Oils Used for Illumination; Analysis of Lubricating Oils, Cylinder Deposits, and of Paint; Pyrometry; Electrical Units; Energy Equivalents; Table, etc.

STEEL CASTINGS.

Professor Arnold in a recent lecture on "Steel Castings," at the Sheffield (England) Technical School, gave the results of his most recent and still unpublished research work. In previous lectures he had dealt with pure iron and carbon steels, it being necessary to do that to get a base line for estimating the influence of other elements on the properties of steel—particularly of manganese and silicon. His data, exhibited in figures on large diagrams, showed the effect of manganese and silicon when introduced into the composition of pure carbon steels. The different mechanical properties of varying compositions of steel, as deduced from a large number of mechanical tests and analyses, were shown in tabular form; and 45 per cent. of carbon was stated to be the critical point for steel castings. If this point were much exceeded the ductility of the castings was speedily lost. With appropriate compositions there was no difficulty in obtaining a maximum stress of 35 tons per square inch, with an elongation of 20 per cent. in two inches. The influence of annealing in toughening steel castings was also dealt with, and the change was proved to be due to two factors; first, the alteration in the structure of the carbide; and secondly, the alteration in the structure of the sulphides. With reference to the objectionable element, sulphur, Professor Arnold showed that ordinary crucibles, ¾ inch thick, were quite incapable of preventing the absorption of the SO (sulphurous oxide) gas present in the melting holes as a product of combustion, and that such sulphur might readily get into the steel. The method of measuring the permeability of crucibles to sulphurous oxide gas was also described.

LETTERS TO THE EDITOR.

This department is set aside as an open door for communications upon all subjects pertaining to the physical properties of the materials of construction. We solicit letters from the colleges, private and governmental laboratories, both at home and abroad, and from all those interested in the field which we represent. It is desired that this department shall be the means of bringing forth and circulating amongst engineers and architects the knowledge gained in these various laboratories. And we shall hope to have it well filled with testing-room kinks, and practical facts of permanent value.

NORFOLK AND WESTERN RAILWAY CO.,
ROANOKE, VA., February, 3d, 1897.

EDITOR OF DIGEST OF PHYSICAL TESTS.

DEAR SIR:—I see, in the October number of the DIGEST OF PHYSICAL TESTS, a scheme for the analysis of white paint ground in oil, by Prof. Thomas B. Stillman, Ph. D., F. C. S. To one interested in this subject, and moderately familiar with the methods of chemical analyses as they apply to paint, the scheme is a rather long one and tedious for ordinary railroad work. As you know, supplies are brought here, as on all railroads, for immediate use, and a delay of four days in the analysis of a material would render the results almost useless. As I take it, this analysis is to discover spurious articles. It is rarely the case when a white lead is bought from a reputable concern, or in fact any company in the lead trust, that we find barium sulphate, clay, or anything but a basic hydrated carbonate of lead. Therefore, I beg leave to ask you, if, as the method published here does not touch on the relative proportions of hydrated and carbonate of lead, which in the main determines the opacity and covering power of white lead, you could not persuade some of your writers to give rapid methods which would determine these points and such questions as would enable the practical chemist to rapidly and accurately value materials.

Yours very truly,
SAMUEL WALLIS, *Chemist.*

STEVENS INSTITUTE OF TECHNOLOGY, March 1st, 1897.

EDITOR OF DIGEST OF PHYSICAL TESTS.

DEAR SIR:—In reply to the letter of Mr. Wallis, regarding the examination of *pure* basic carbonate of lead, I would suggest as follows: If qualitative analysis has shown the paint to be ($2PbCO_3$), (PbH_2O_2), (dry, not ground in oil), proceed as follows:

Take 1 gram of the paint, transfer to a No. 3 beaker, add sufficient dilute nitric acid and warm gently until solution is complete. Dilute sulphuric acid is added in slight excess and $10^{c.c.}$ of alcohol. Allow to stand twenty minutes; filter off the $PbSO_4$; wash well with water; dry; ignite and weigh as $PbSO_4$. The weight of $PbSO_4$ multiplied by 0.85258 will give the weight of ($2PbCO_3$), (PbH_2O_2).

If the white lead is ground in oil ("Paste White Lead," containing about eight per cent. of oil), it will be necessary to extract the oil before the above determination of lead can be made. The usual solvent for the oil is Petroleum ether. Thompson* prefers Benzol, C. P. Twenty grams of the paint are treated with sufficient Benzol, in a Soxhlet apparatus, and the oil extracted. By evaporation of the Benzol in a weighed beaker the amount of oil is determined.

Hurst† treats the lead paint with strong nitric acid, whereby the oil is decomposed "into an insoluble greasy matter;" this does not interfere with the determination of the lead as sulphate. If, however, the oil is to be determined also, then he recommends the use of Petroleum ether. After the extraction of the oil, either by Benzol or Petroleum ether, the residue is dried at 102° C., and weighed portions taken therefrom for the determination of the lead, as sulphate.

Instead of determining the lead as sulphate, many chemists prefer to dissolve the dried lead paint in acetic acid to a clear solution, and precipitate the lead with bichromate of potash as lead chromate. This latter is weighed as $PbCrO_4$ in a Gooch crucible and the weight found calculated to ($2PbCO_3$) (PbH_2O_2).

If it be desired to determine the carbonic acid in the paint, use is made of the "Schrotter" carbonic acid apparatus or the "Geissler" apparatus.‡

Thompson recommends the absorption method for CO_2 deter-

***Journal Society Chemical Industry*, XV, p. 432.

† *Painter's Colors, Oils, and Varnishes*, p. 44.

‡ *Fresenius Quant. Anal.*, I, p. 447.

mination; consult *The School of Mines Quarterly*, XIV, p. 318, for a description of the different methods of determination of CO_2 in paints.

The water of hydration, in the dried paint, is found by calculating the amount of lead sulphate or chromate into lead oxide, and subtracting this amount of lead oxide, plus the amount of CO_2 found, from 100. The difference is the water of hydration. The water of hydration cannot be determined accurately in paint from which the oil has been extracted, since a small amount of organic matter remains which vitiates the result.

The Hygroscopic water is determined by drying a sample of the paint at 105° C. to constant weight. The loss represents moisture.

It would thus appear that the "rapid" method required by Mr. Willis for the analysis of pure basic carbonate of lead paint, would be the direct determination of the lead as sulphate or chromate and then calculation to the formula of $(2PbCO_3)$ (PbH_2O_2). Consult *Select Methods in Chemical Analysis*, Crooke's, p. 366; *Chemiker-Zeitung Repertorium*, 1893, p. 196.

Respectfully yours,

THOS. B. STILLMAN.

A NEW USE FOR COTTON.—It is stated that a "chemical discovery of enormous public interest has just been made by a London analyst, who has already secured the assistance of the British Government for a practical test of its claims. This is no less than a direct solvent for cotton, which is itself volatile, and leaves behind it nothing but pure cotton cellulose—that is to say, cotton fibre reduced to an amorphous pulp. This substance differs radically from nitro-cellulose, the highly inflammable and odorous compound which in one of its forms becomes gun-cotton and in another vegetable ivory. The possible uses of the new material are innumerable. It has already been experimentally molded into buttons and billiard balls, being less than half the price of celluloid or xylonite, while the fact that it is incombustible will enable it to be adopted for many domestic uses for which the camphorated material is unsuited. When it is added that the specific form of the departmental encouragement above referred to is a definite contract for sacks in this new cotton pulp, to which the name of viscose is given, it will be understood that we are on the threshold of a new industry in which Manchester is not unlikely to find itself directly interested."

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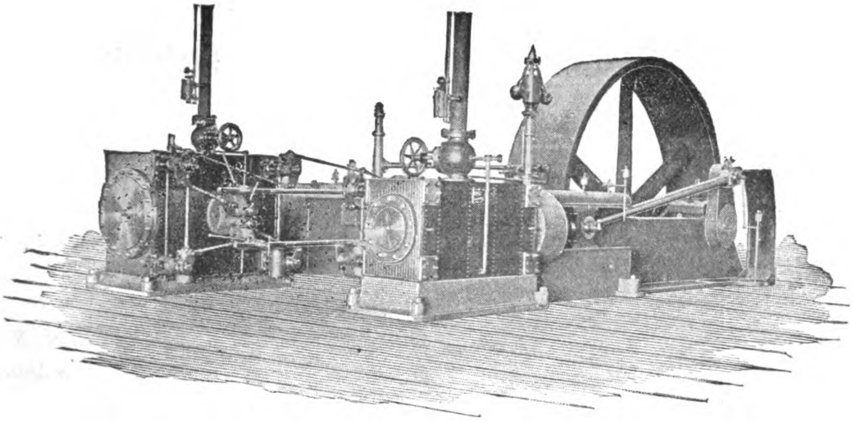

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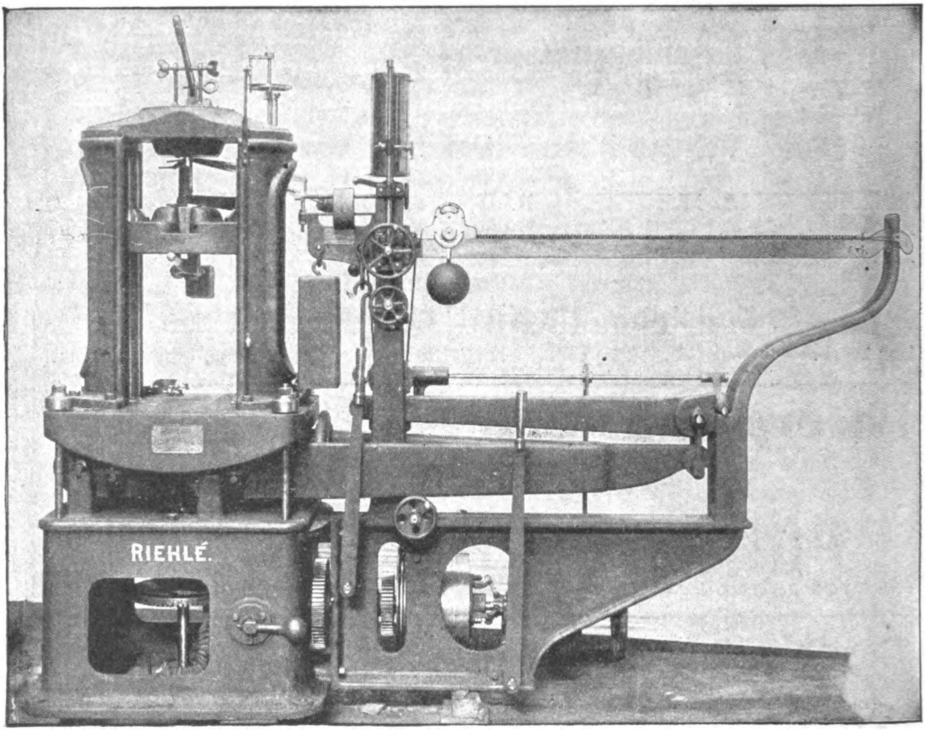

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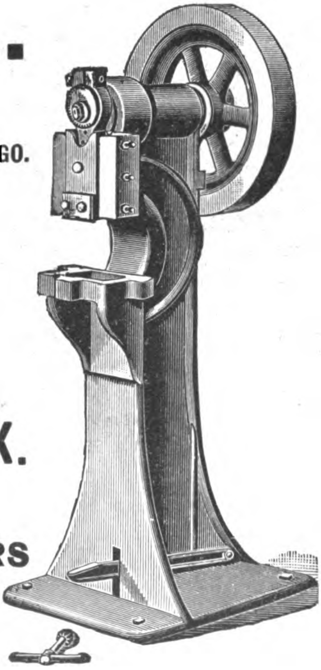

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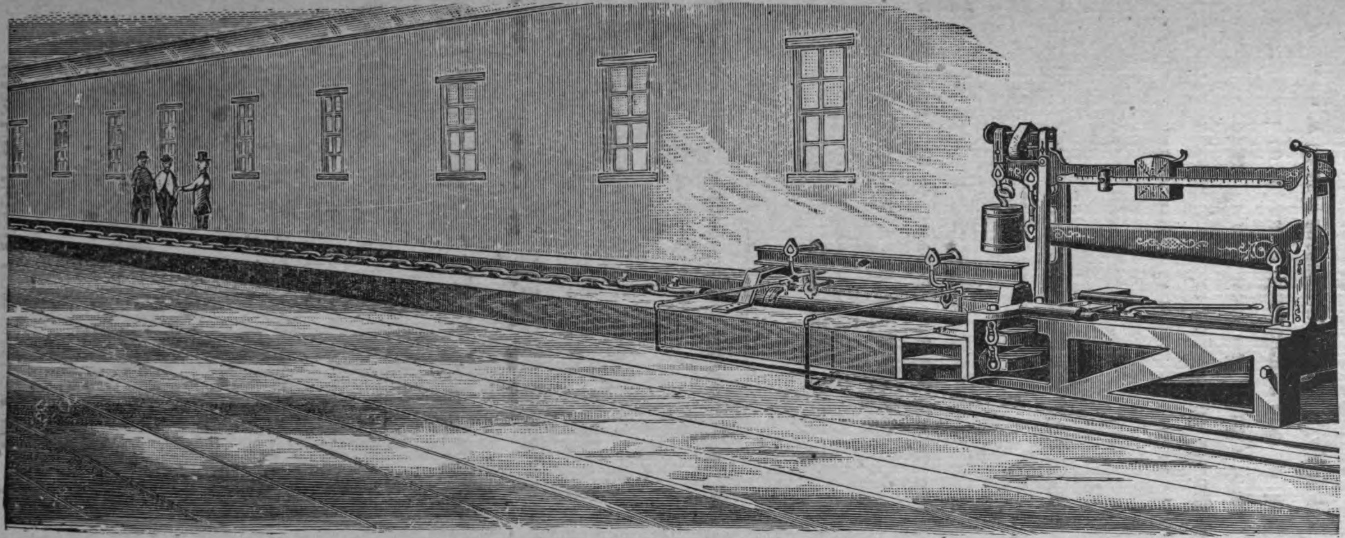

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OF

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AND

Laboratory Practice.

A résumé of Practical Tests made in the Laboratories of the World.

JOSEPH W. BRAMWELL, EDITOR.

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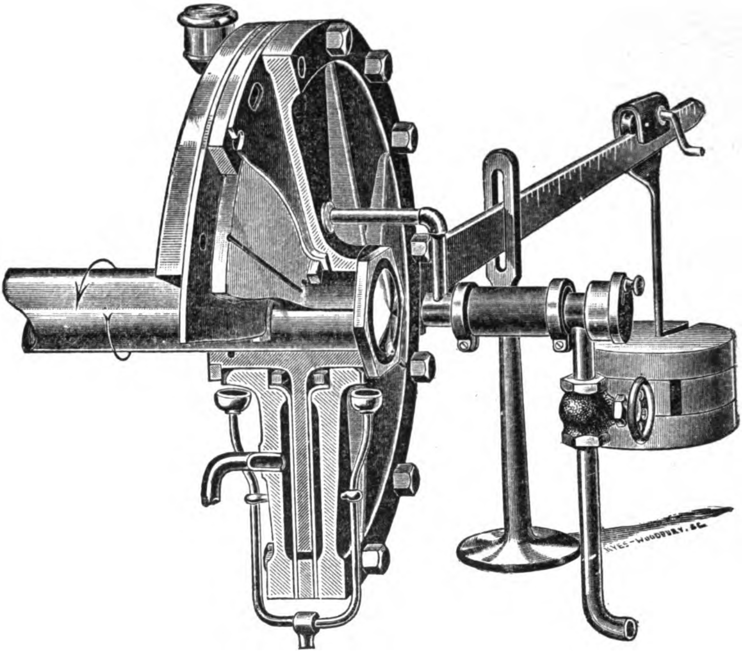

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Digest of Physical Tests.

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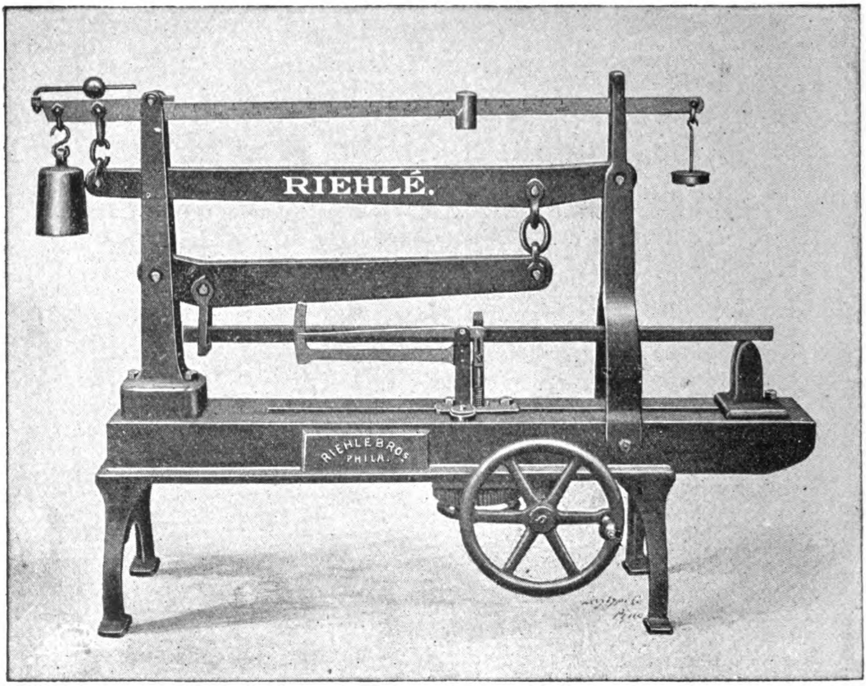

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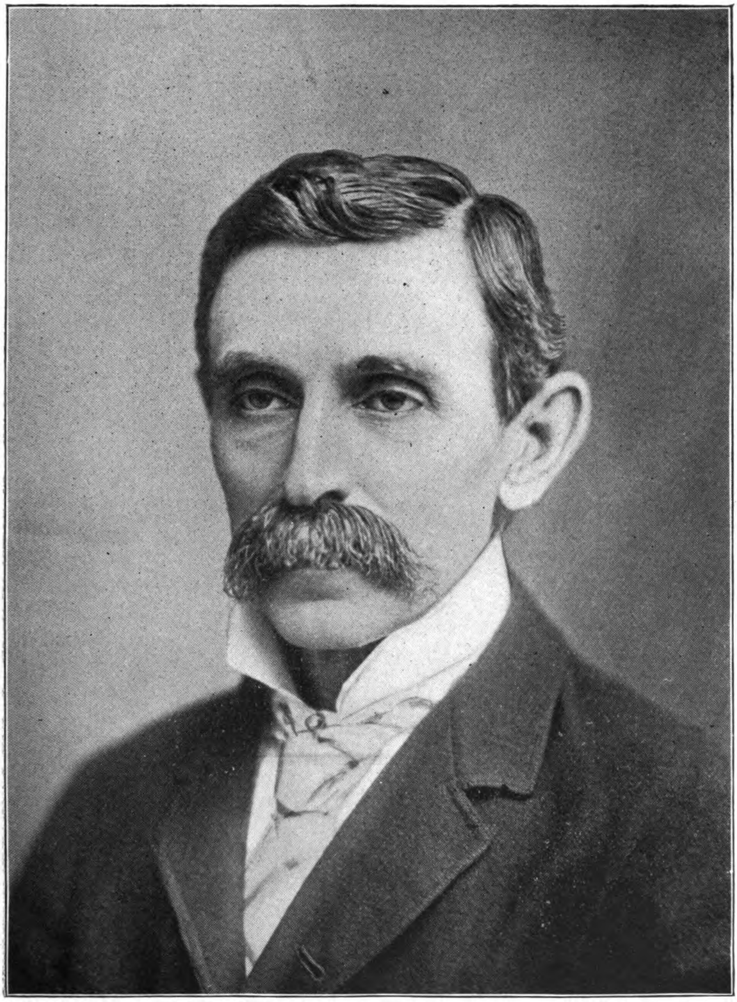


George Brooke Roberts.

Digest of Physical Tests.

A RÉSUMÉ OF PRACTICAL TESTS MADE IN THE
LABORATORIES OF THE WORLD.

Vol. II. JULY, 1897. No. 3.

GEORGE BROOKE ROBERTS.

FIFTH PRESIDENT OF THE PENNSYLVANIA RAILROAD CO.

By Frederick A. Riehlé.

GEORGE BROOKE ROBERTS, President of the Pennsylvania Railroad Company, died January 30th, 1897, at his country home at Bala, near Philadelphia. He was born June 15th, 1833, at the old homestead in Montgomery County, Pa. He adopted the profession of engineer, and was graduated at the Van Rensselaer Polytechnic Institute, Troy, N. Y., at the early age of seventeen years. He afterward took a post-graduate course of a year. He entered the service .of the Pennsylvania Railroad Company in 1851 as rodman and has successively occupied positions of increasing trust and responsibility in the same company up to the time of his death. In 1862 Mr. Roberts became assistant to the President of the company, J. Edgar Thomson; in the year 1869 Mr. Roberts was elected to be Fourth Vice-President. Shortly after he was promoted to the office of Second Vice-President. In 1874 he was advanced to the position of First Vice-President. Upon the retirement of President Thomas A. Scott in 1880, he was elected President of the great corporation, which position he occupied up to the time of his death.

The career of Mr. Roberts was a very remarkable one in many respects. He was studious, ambitious, and intelligent; his capabilities were measured and appreciated—commencing as he did from rodman, it is evident nothing but active, indefatigable service could win him the highest position of honor in the great company. Mr. Roberts ended his life in the neighborhood of his birth, surrounded by his family and a large number of friends who greatly mourn his decease. His life and career together form a brilliant example of true success, which alone is the outcome of integrity and honor.

[It was intended to have this illustration and comments in an earlier number of DIGEST, but the matter for this number was prepared, hence the unavoidable delay in presenting the above before. —EDITOR.

PAINT FOR IRONWORK.—Prof. Spennrath, director of the Technical School of Aix-la-Chapelle, lately won the $2,000 prize offered by the Society for the Advancement of the Industrial Arts for the best essay on Protective Paints. The prize was not won simply by theoretical demonstrations, although the professor furnished scientific reasons also, but by most carefully conducted practical experiments with various pigments and oils, covering several years' time. The results demonstrated that a properly made paint of graphite and boiled linseed oil is the most suitable for protecting structural iron work, roofs, etc., exposed to the destructive agencies of heat, cold, storms, etc.

CEMENT LABORATORY OF THE CITY OF PHILADELPHIA.—In the following pages we take pleasure in reprinting the paper on the *Cement Laboratory of the City of Philadelphia*, by Richard L. Humphrey. To ensure success in a perfect method of testing cement, a thoroughly well-arranged Laboratory is an absolute necessity. This involves considerable originality, much experience and toil. In the arrangement of this Laboratory Mr. Humphrey has shown how fully he comprehends the subject, theoretically and practically. The disposition of machines, some of which are original in design, tanks, etc., point conclusively that time and attention to detail are important elements, and figure largely in the success of cement testing.

THE CEMENT LABORATORY OF THE CITY OF PHILADELPHIA, ITS EQUIPMENT AND METHODS.

By Richard L. Humphrey, Active Member of the Club.

[Before the meeting of the Engineers' Club of Philadelphia, October 3d, 1896.]

INTRODUCTION.—The Testing Laboratory (Department of Public Works, Bureau of Surveys), consisting of the Cement, Physical, and Chemical Laboratories, occupies Rooms 56, 58, and 60 in the southwestern portion of the Public Buildings. In the first mentioned of these laboratories is inspected and tested practically all the cement used in municipal work.

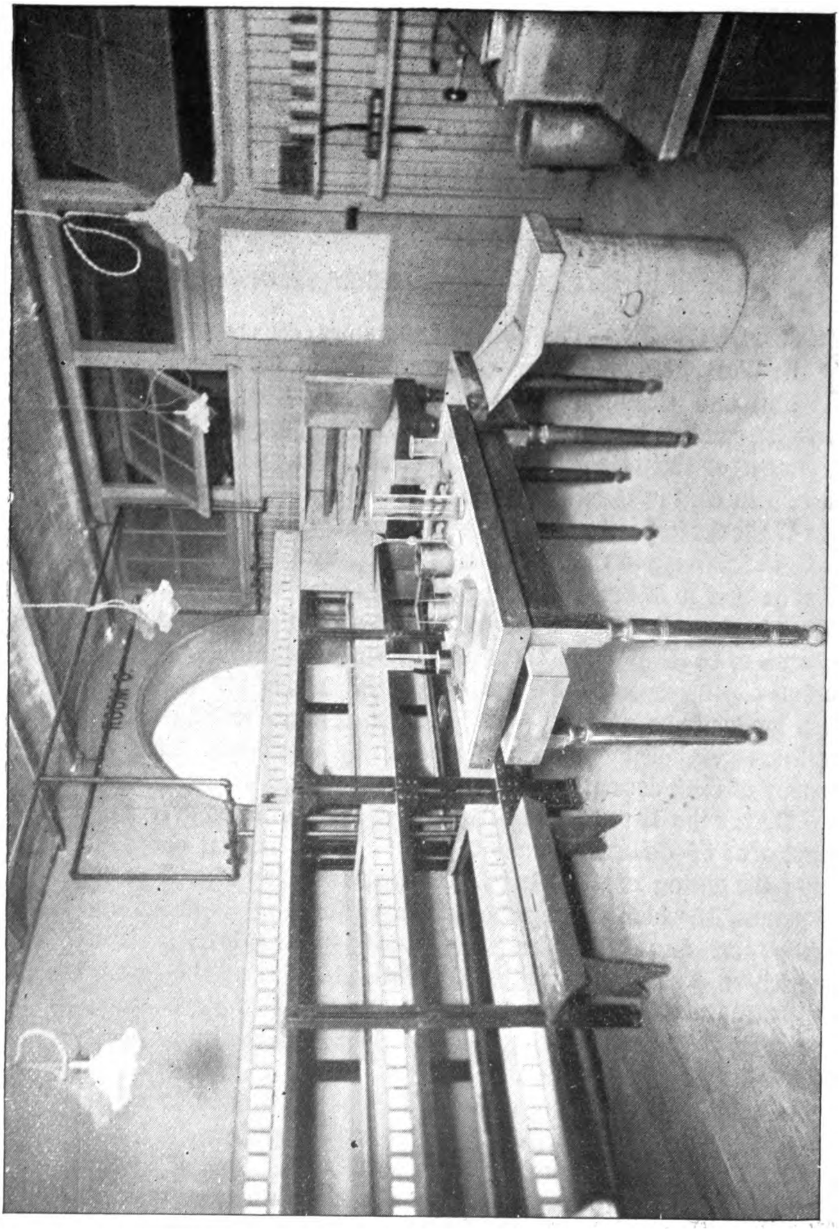
While the inspection and testing of cements was inaugurated in the Bureau of Surveys in the early part of 1890, it was not until the fall of 1892 that a laboratory was permanently established. Since that time it has been in constant service, each year multiplying the amount of work to be done by the increasing demands made upon it by the various city bureaus. The scope of its work has, at the same time, been gradually broadening—this development necessitating increased facilities. Although seriously hampered by insufficient force, the amount of work accomplished has been very great.

During the last four years there have been collected over 2,000 samples of 66 different brands of cement, both natural and Portland; the testing of these has involved the molding of over 30,000 briquettes, of which over 25,000 have been broken. With the constantly-increasing skill and experience, a system has been gradually evolved, until to-day it is well established and in successful operation.

It will be the endeavor of this paper to explain in detail the apparatus employed and the system under which all cement used in city work is inspected and tested.

A set of specifications (whose requirements are fixed in a manner to be described further on), adopted as the city standard, form the basis for the acceptance or rejection of a shipment of cement. Any brand of cement is permitted to be used which meets these requirements.

COLLECTION.—The tests are made from samples taken from actual



Immersion Tanks. Mixing Table. Moist Closet. "Hot Water" Apparatus.

FIG. 11.—VIEW OF THE CEMENT LABORATORY.

shipments on the work, and not from samples furnished indiscriminately.

Notification of Shipments.—Each inspector is supplied with printed postal cards, which he fills out and mails immediately to the Inspector of Cements upon the receipt of each shipment of cement on his work. This card states the brand and the number of bags or barrels in the shipment, together with the time and place of delivery and the purpose for which it is to be used. The shipment is inspected and a sample is taken sufficient for the required tests.

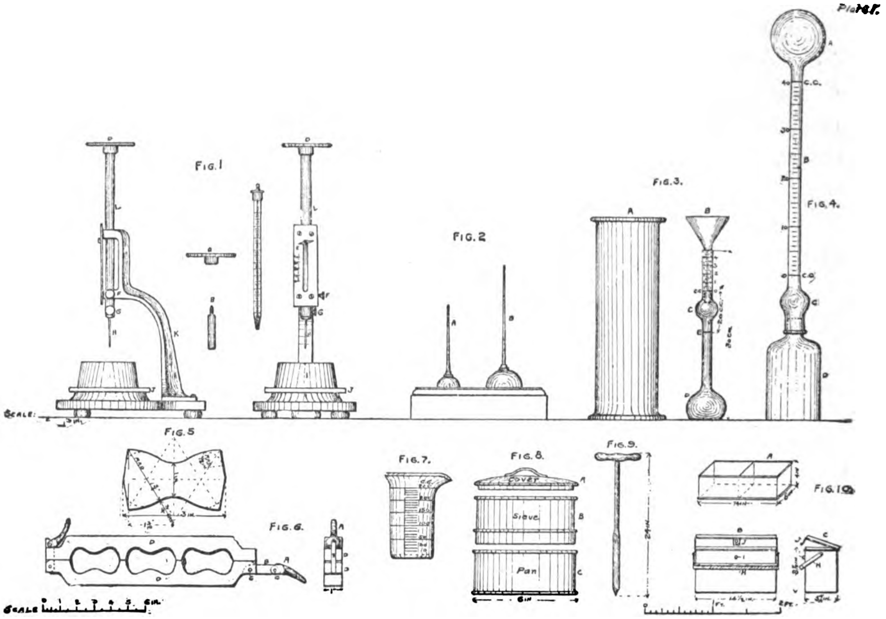
Sampling.—This sample is obtained by taking a small quantity from one barrel in every five or ten, depending on the size of the shipment, the cement being taken from the heart of the barrel in order to secure a fair sample of its fineness and quality. In large shipments (500 barrels and upwards) a small hole is bored near the middle of the barrel, through which the sample is drawn by means of a sampling auger, Fig. 9. The notification card is placed on this sample.

Collection Cans.—The sample is brought to the laboratory in special collection cans. There are two types of these cans, one holding two and the other four samples. The latter type is shown in Fig 10. They are made of japanned tin and are in two parts; the can proper, *K*, holding two samples, and the upper tray, *A*, holding the remaining samples, fitting into the can, *K*. Each compartment is 7 inches long, 5 inches wide, and 4 inches deep, and holds about seven pounds.

RECORDING.—On reaching the office the notification card is replaced by one bearing the laboratory number by which the sample will be referred to thereafter. The data on the notification card is entered in the Record Book, which eventually contains all the information relative to this sample, a record being kept of the number of the sample, the brand, the date, and place of collection, whether the shipment was in bags or barrels, the fineness in per cent., date and hour of molding the briquettes, time of setting and the temperature of the air, the specific gravity, the results of the hot-water tests, and the tensile and compressive strength, both neat and with various proportions of sand for different periods of time.

The plan, Fig. 12, shows the general arrangement of the various laboratories: the positions of the various apparatus (which have been arranged so as to afford the greatest convenience), is shown in detail in the Cement and Chemical Laboratories.

MAKING BRIQUETTES.—For weighing the material to be used for making the tests, the laboratory is provided with a pair of scales sensitive to ½ gramme under a load of 2 kilogrammes in each pan. The mixing and molding is done on a specially-designed table (Figs. 11, 12, and 14), consisting of two parts, each having a plate-glass top, one 24 inches long by 18 inches wide, on which the mixing and molding is done; and the other, which is 3 inches above the level of the former, is 4 feet long, 2 feet wide, and is used for making the tests for time of setting, and for marking and removing the briquettes from the molds.



FIGS. 1 TO 10.—DETAIL APPARATUS USED IN MAKING CEMENT TESTS.

The sample of cement collected as just described, composed of portions taken from various barrels, is now thoroughly mixed by passing it through what is known in the laboratory as a No. 20 sieve. A small portion is then weighed out and made into a paste by gradually adding clean water from a graduate (Fig. 7). The quantity of water required to produce a stiff, plastic paste, of about the consistency of molding clay, is thus obtained.

Neat.—Having determined, by the above test, the proper percentage of water required for the neat tests, 1,000 grammes of the sample are weighed out, and placed upon the mixing table; a basin is then formed with this material, into which the proper percentage of clean water is poured, the material is turned into the basin by the aid of a trowel, and the mixing is completed by thoroughly kneading the mass to the proper consistency with the hands. It is then firmly pressed into the molds with a trowel and the surface smoothed. The mold is then turned over, and the same operation is repeated. The briquettes are kept in the molds until they can be removed without injury.

Molds.—The molds are of brass, both single, and in gangs of three and five. The three-gang mold is shown in Fig. 6; it is in two parts, $D—D$, to facilitate the removal of the briquette, the parts being held together by means of a clamp, $A—B$. The gang molds are usually used, the briquettes being molded three or five at a time, according to the rate of setting.

The form is that recommended by the American Society of Civil Engineers, except that the corners have been rounded by curves of ½ inch radius. This form is found to be more easily molded, and afterwards more easily adjusted in the testing machine.

The molds are kept clean, and, before the briquettes are molded, are wiped with a cloth moistened with machine oil.

With Sand.—In making the sand briquettes, the following method is pursued: The sand and cement, in proper proportions, are weighed out and thoroughly mixed dry on the mixing slab, then the process is the same as described for the neat briquettes.

In determining the proper percentage of water for sand briquettes, the following formula is used;

$$E = \tfrac{2}{3} NA + 60,$$

where, $N =$ weight (in grammes) of water required for 1,000 grammes of neat cement

$A =$ weight of cement (in kilogrammes) in 1,000 grammes of the sand mixture

$E =$ weight (in grammes) of water required for the sand mixture.

A table has been prepared based on this formula, as modified by experience, giving the proper percentage of water to be used for different proportions of sand. This has been found not only to produce more uniform results, but also to greatly facilitate the work of mixing. The standard proportions are one of cement to two of sand for natural cement, and one of cement to three of sand for Portland cement.

Standard Sand.—The sand is crushed quartz, all of which passes a No. 20 sieve and is retained on a No. 30 sieve.

Mixing and molding by hand has been found to produce more uniform results than can be obtained with any of the machines now in use. Besides, the mass being under perfect control, the proper consistency is reached more quickly, and can be told at once by an experienced person by its appearance and peculiar feeling.

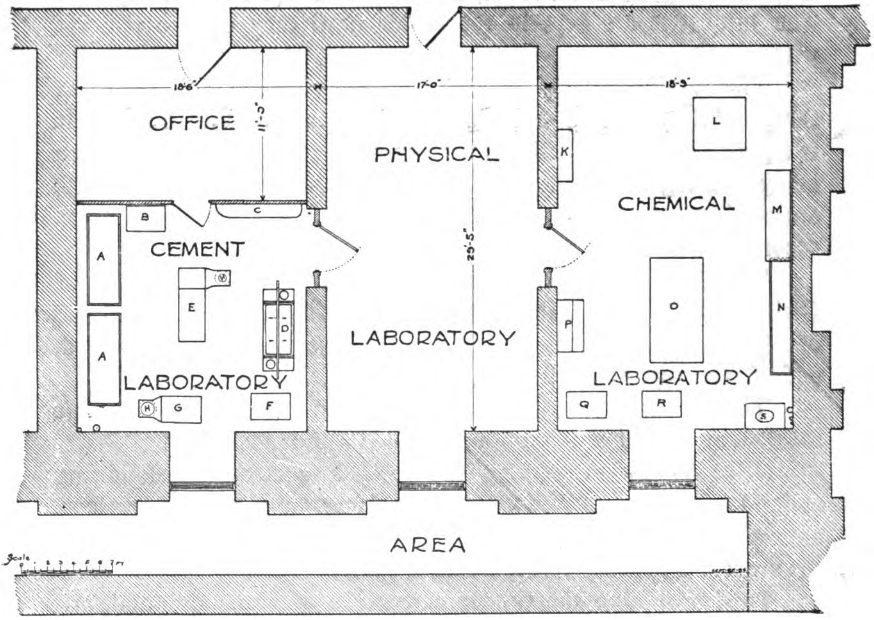


FIG. 12.—GENERAL PLAN OF THE LABORATORIES.

A.A.	Immersion Tanks.	G.	Weighing Table.	N.	Sink.
B.	Moist Closet.	H.H.	Waste Cans.	P.	Reagent Closet.
C.	Shelves.	K.	Apparatus Closet.	Q.	Balance.
D.	"Hot Water" Apparatus.	L.	Hood.	R.	Microscope.
E.	Mixing Table.	O.	Working Table.	S.	Wash Basin.
F.	Testing Machine.	M.	Table for Distillations, etc.		

In mechanical mixing machines similar to Faija's, the cement has a tendency to ball, especially if a quick-setting one, incipient setting often taking place during the removal of the mass from the mixer, which necessitates retempering before molding can be attempted.

The Boehme hammer requires about 3 minutes to mold each briquette or about one-half hour to mold ten, whereas the same number can be molded by hand in about 15 minutes. Comparative tests have shown that briquettes molded by hand give higher results and nearly as uniform as those made by the Boehme hammer apparatus.

In France and Germany, it is the rule to mix slow-setting cements 3 minutes, and quick-setting ones 1 minute before molding. Experience in this laboratory has been that greater uniformity in the results is obtained by mixing to the proper consistency and molding as quickly as possible. The aim being to have the cement in the mold before incipient setting commences.

The briquettes, prior to their immersion in water, are kept in moist air for a period of 24 hours, except in the case of the 24-hour tests, in which they are immersed after hard set.

Moist Closet.—For this purpose there has been designed a moist closet (Figs. 11 and 12), which has replaced the old method of covering briquettes with a damp cloth. This closet, which is made of soapstone 1¼ inches thick, is supported by a wooden frame and is 3 feet long, 2 feet high, and 18 inches wide. Along the front is a strip of soapstone, 3 inches wide, forming a basin of the bottom of the closet in which the water is placed for keeping the air moist. The doors are made of wood, covered with planished sheet copper, and are rabbeted to fit tightly. There are two sets of shelves, the lower being a wooden rack, and the upper is formed of strips of plate glass, 33 inches long, 3 inches wide. When closed, the closet is perfectly tight, the water in the bottom keeping the air moist, preventing the briquettes from drying out, and thus checking the process of setting.

This apparatus, aside from its obvious convenience, possesses marked advantages over the old method. The cloth could never be made or kept uniformly damp, it dried out unequally, which rendered it impossible to submit all briquettes to the uniform treatment that can be obtained in the moist closet.

Briquettes which have been removed from the molds are placed on edge on the glass shelves, while the molds containing the briquettes too soft to be removed are placed on the racks.

Numbering.—The number of the sample is marked on each briquette; each group of briquettes after the first group being indicated by an additional letter, thus the series of neat briquettes are marked: 2098; mortar 1 to 2, 2098A; mortar 1 to 5, 2098B, etc.

A thin layer of neat cement is spread over one end of briquettes containing four or more parts of sand, to make a smooth surface for numbering on.

IMMERSION.—*Tanks.*—For preserving the briquettes in water, small agate pans were formerly used, which have now been replaced by large soapstone tanks, six in number, each 7 feet long, 2½ feet wide and 7 inches deep, outside measure, having a capacity for over 10,000 briquettes. There are at the present time in these tanks about 4,000 briquettes of various ages from four years down. These tanks are shown in detail in Fig. 13.

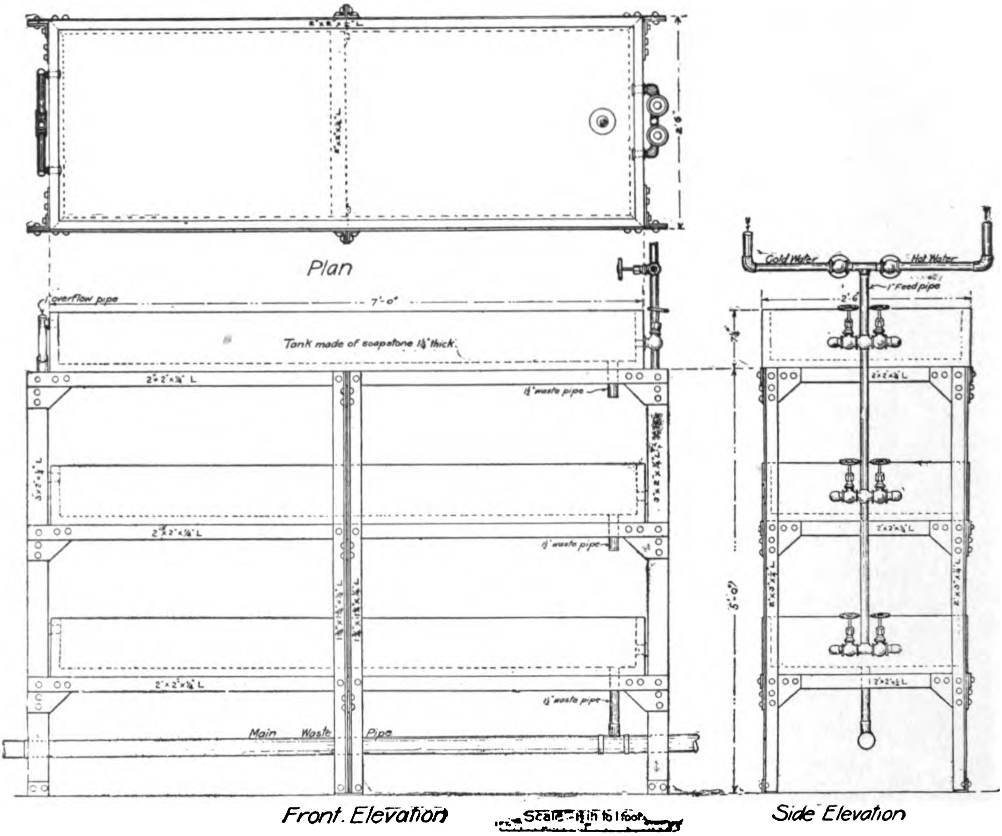


FIG. 13.—DETAILS OF THE IMMERSION TANKS.

They are supported by two frames, formed of steel shapes. Each tank is supplied by a continuous stream of water, at a temperature never less than 70° F., which enters at one end near the bottom through two pipes, and overflows through two pipes at the other end, the pipes being so arranged that the water flows uniformly through the tanks. The rate of the flow through the tanks is controlled by a valve on each supply pipe. The main feed pipe is supplied with hot and cold water, from pipes provided with valves, by which the temperature of the mixture is regulated.

The tanks were made of soapstone because it is non-absorptive, non-corrosive, and easily cleaned. The water is previously filtered before entering the tanks, and is always clean and pure. It has been the experience in the laboratory, that where briquettes are immersed in pans the water becomes strongly alkaline unless it is frequently changed and the pans cleaned. Inasmuch as these tanks have replaced three dozen small pans (22 inches x 15 inches x 3 inches) it is evident that besides the advantages of having all briquettes immersed under perfectly uniform conditions, a very great amount of time and labor is saved.

The briquettes are immersed on edge, and placed a slight distance apart so as to permit the free circulation of water around them. On the outside of the tank opposite each row, celluloid cards are glued, on which are marked in pencil the inclusive numbers of the row. The briquettes being arranged in the tanks in consecutive order, they are easily located.

TIME OF SETTING.—For determining the time of setting, the laboratory is provided with a Vicat needle and Gilmore's wires.

Vicat Needle.—The Vicat needle illustrated in Fig. 1, consists of a frame *K*, bearing the movable rod *L*, having the cap *D* at one end and the needle *H* having a circular cross-section of one square millimetre at the other. The screw *F* holds the needle in any desired position. The rod carries an indicator which moves over a scale (graduated to centimetres) borne by the frame *K*. The rod with the needle and cap weighs 300 grammes; the paste is held by a conical hard rubber ring *I*, 7 cm. in diameter at base, 4 cm. high, resting on the glass plate *J*, 15 cm. square.

To determine if the paste is of normal consistency, the needle *H* and cap *D* are replaced by the rod *B* (1 cm. in diameter) and the cap *A*. The rod *L* then weighing 300 grammes shall stop sinking 6 mm. from the bottom of the ring, 4 cm. deep, filled with paste.

For neat pastes the setting is said to have commenced when the polished steel needle weighing 300 grammes does not completely

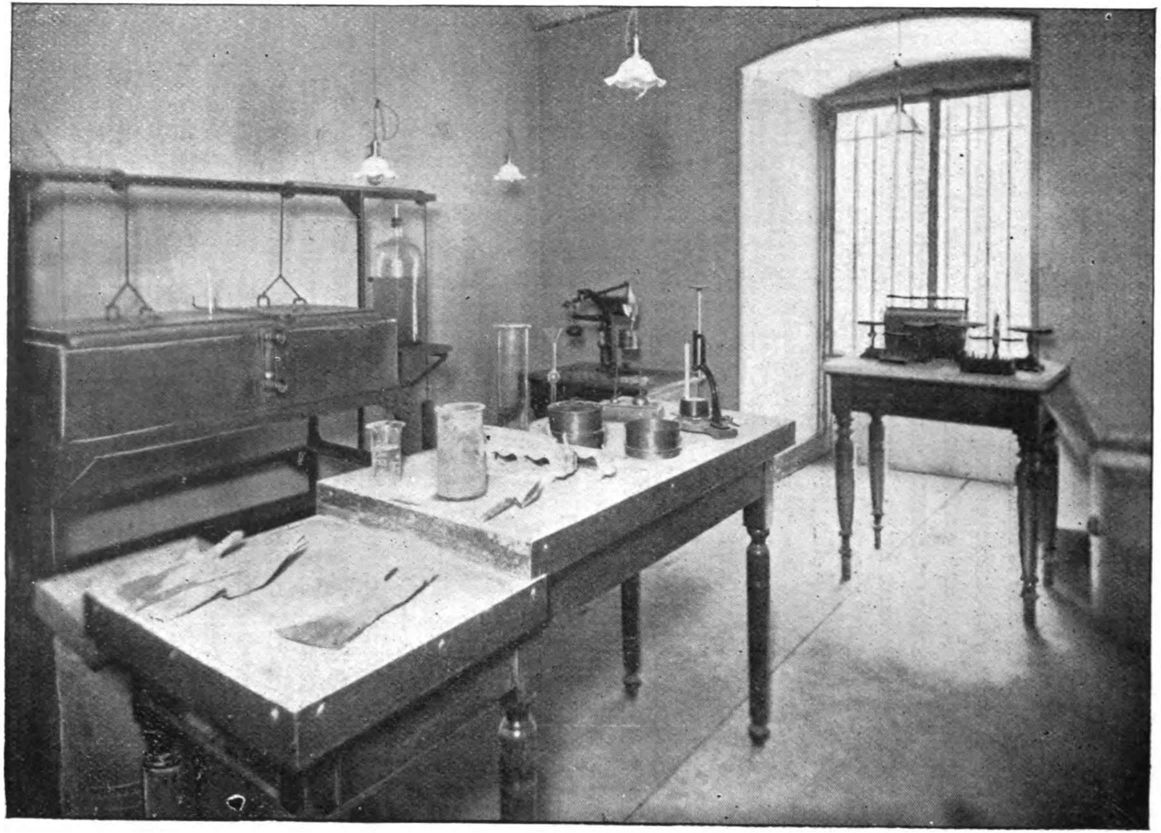


FIG. 14.—VIEW OF THE CEMENT LABORATORY.

traverse the mass of normal consistency, confined in the rubber ring, and the setting is said to be terminated when the same needle gently applied to the upper surface of the mass does not sink visibly into it.

A thermometer *C* graduated to $\frac{1}{5}$° C. is stuck into the mass and the increase of temperature of mass during setting can be thus observed. The paste is kept in the moist closet during the operation, being removed only to make trial tests of the setting.

This is the apparatus adopted by the French Commission * and the Society of German Cement Manufacturers.

Gilmore's Wires.—Gilmore's wires are commonly used in this country for determining the time of setting. They consist of two brass balls (Fig. 2), each bearing a wire having a circular section. For the initial set the section is $\frac{1}{12}$ of an inch in diameter, the ball and wire weighing ¼ of a pound. For hard set the section is $\frac{}{12}$ of an inch in diameter, and the weight is one pound.

For determining the time of setting by this method, cakes of neat cement, 2 or 3 inches in diameter, ½ inch thick, with thin edges, are made on small pieces of glass. When the paste resists the gentle application of the ¼ pound wire the cement has attained its initial set and when the pound-wire, gently applied to the surface of the paste, ceases to make an impression, the cement has its hard set. For quick determinations these wires give sufficiently accurate results for practical purposes. For more accurate determinations the Vicat needle is used.

FINENESS.—*Sieves.*—In determining the fineness of a cement, three sieves are employed, and are known in the Laboratory as the No. 50, No. 100, and No. 200, they having approximately 2,500, 10,000, and 40,000 meshes per square inch; the sieve is made of brass wire cloth, the diameter of the wire being .0090, .0045, and .0020 of an inch, respectively. In addition there is a No. 20 and a No. 30 sieve for determining the relative sizes of various sands. These have 400 and 900 meshes per square inch respectively, the diameters of the wires being respectively .0165 and .0123 of an inch. The sieves are provided with a tightly-fitting cover and pan (Fig. 8), which prevents the loss of the fine powder during the operation of sieving.

The scale for ascertaining the fineness has a capacity of 500 grammes in each pan, and is sensitive to one decigramme under full

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*** Commission des Méthodes d'Essai des Matériaux de Construction.**

load. This scale, together with that for weighing the material for making the briquettes, rests on a table (see Fig. 11) 3 feet long, 2 feet wide, having a soapstone top.

Method.—The fineness (expressed in the percentage of residue left on the sieve) is determined by passing 100 grammes of cement successively through the No. 50, No. 100, and No. 200 sieves. The sieve is gently tapped and shaken with the hand until, after a few minutes' shaking, no appreciable quantity passes through the sieve. An automatic sieving arrangement has been designed and will be put into operation in a few weeks. This machine is designed to sieve four samples at one time. The motion is to and fro, a slight shock

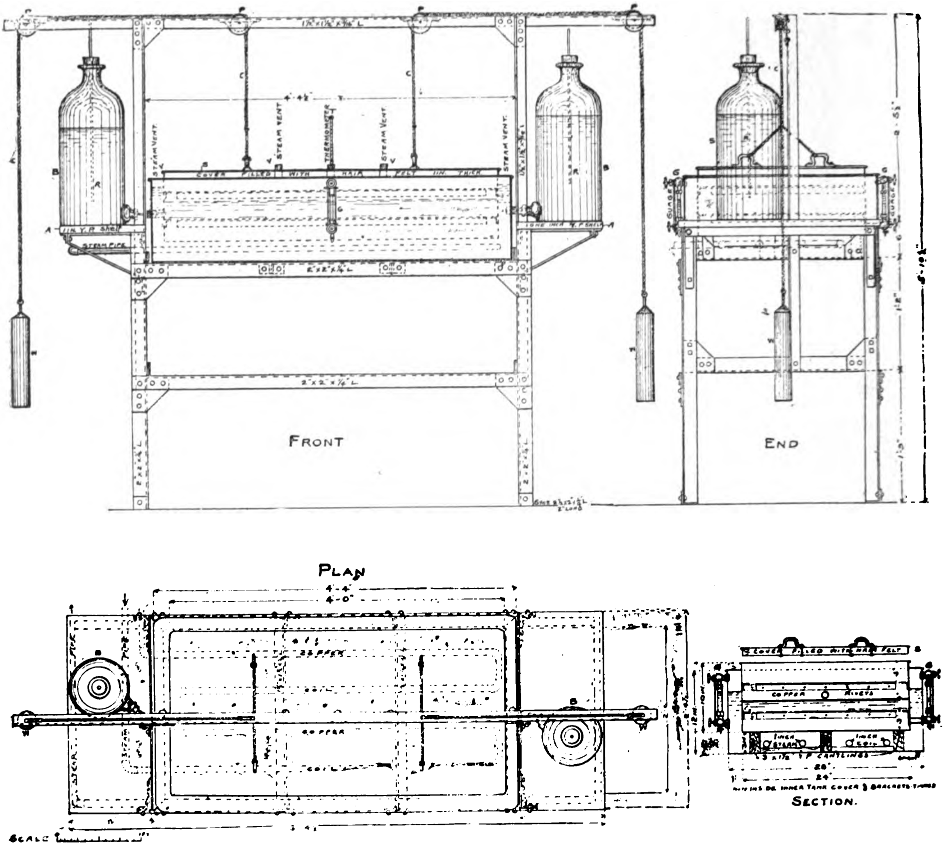


FIG. 15.—DETAILS OF THE "HOT WATER" APPARATUS.

being given to the sieve at the end of each stroke. The apparatus will stop automatically at the end of a fixed number of revolutions of the driving mechanism.

SPECIFIC GRAVITY.—The specific gravity has replaced the old weight per bushel test.

There are two forms of apparatus in the Laboratory: one according to Candlot (Fig. 4), and the other according to Le Chatelier (Fig. 3).

Candlot's Apparatus.—Candlot's apparatus (Fig. 4) consists of a graduated tube *B*, terminated by a bulb *A*, which fits tightly on the ground neck of a flask *D*. The liquid used in making the determinations is introduced in the tube *B* in sufficient quantity to bring the level of the liquid above the zero point, when the tube is reinverted on the flask *D*.

A record is made of this height and the liquid is returned to the bulb *A*, the flask *D* is removed, into which a known weight (usually 100 grammes) of cement is introduced. The flask *D* is again connected with the tube *B*, and the whole is agitated to expel the air bubbles. The new height of the liquid is read, and the difference between this and the former reading is the volume displaced by the known quantity of cement.

The connection is rubbed with vaseline to render it tight, but even then, unless the operator is very careful, the consequent losses affect the accuracy of the results. This apparatus has been abandoned for the more convenient and precise form of Le Chatelier.

Le Chatelier's Apparatus.—This apparatus consists of a flask *D* (Fig. 3) of 120 c.cm. capacity, the neck of which is about 20 cm. long. In the middle of this neck is a bulb *c*, above and below which are two marks engraved on the neck; the volume between these marks *E* and *F* being exactly 20 c.cm. Above the bulb the neck is graduated into $\frac{1}{10}$ c.cm. The neck has a diameter of 9 mm. Benzine being free from water and being neither very volatile nor hygroscopic, is used in making the determinations.

The specific gravity can be determined in two ways:

(1) The flask is filled with benzine to the lower mark *E*, and 64 grammes of powder are weighed out; the powder is carefully introduced into the flask by the aid of the funnel *B*. The stem of this funnel descends into the neck of the flask to a point a short distance below the upper mark. The cement cannot stick to the sides of the neck and obstruct its passage. As the level of the benzine approaches

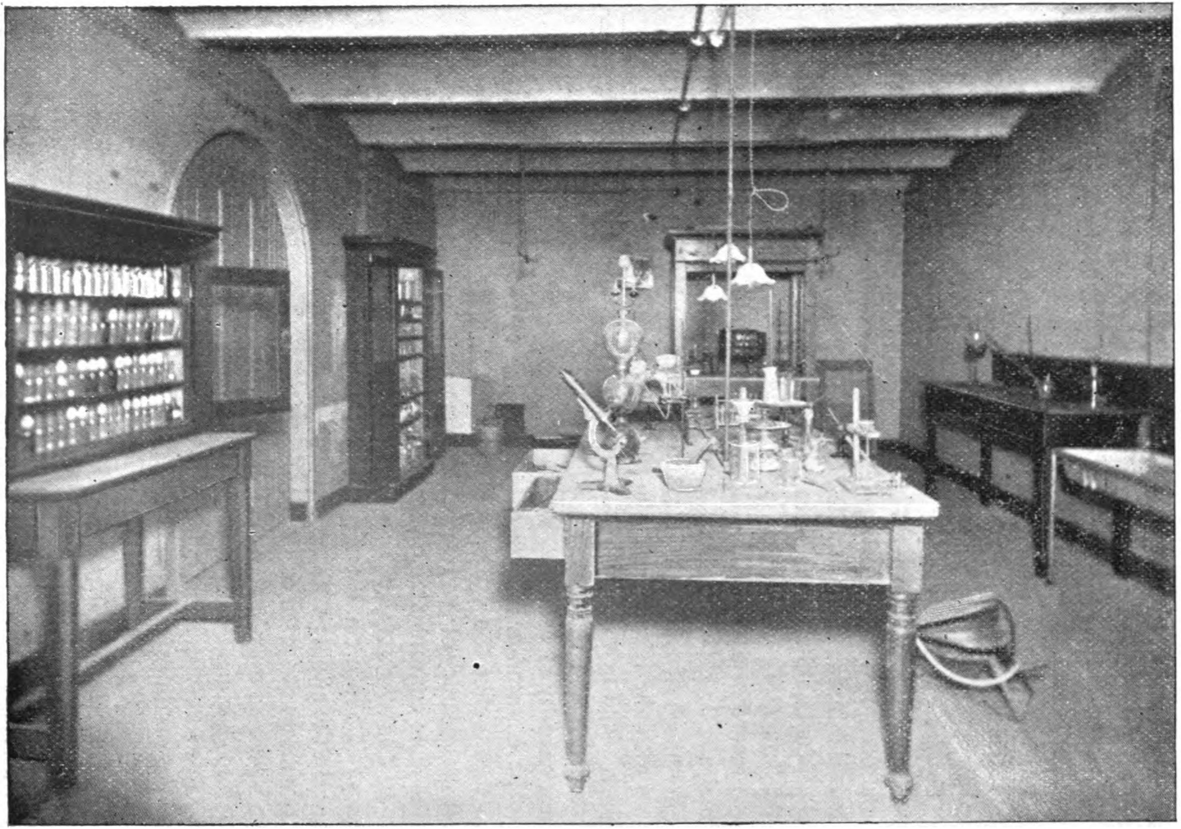


FIG. 16.—VIEW OF THE CHEMICAL LABORATORY.

the upper mark, the powder is introduced carefully and in small quantities at a time, until the upper mark is reached. The difference between the weight of the cement remaining and the weight of the original quantity (64 grammes) is the volume which has displaced 20 c.cm.

(2) The whole quantity of cement is introduced and the level of the benzine rises to some division of the graduated neck; this reading + 20 c.cm. is the volume displaced by 64 grammes of cement. The specific gravity is then obtained from the formula:

$$Sp.\ G. = \frac{\text{Weight in air.}}{\text{Displaced weight or loss of weight in water.}}$$

The flask during the operation is kept immersed in water in a jar *A*, in order to avoid any possible error due to variations in the temperature of the benzine. The cement in falling through the long tube completely frees itself from all air bubbles. The results obtained agree within .02.

HOT WATER TESTS—*Apparatus.*—Fig. 15 shows in detail what is commonly used for the "hot water" or "boiling tests." It serves a dual purpose in this Laboratory:—(1) It is used in the determination of the specific gravity and absorption of blocks of stone, bricks, concrete, etc., and (2) for seeking evidence of unsoundness in cements.

It consists of two tanks, made of 22 ounces copper, and placed one within the other, the inner tank being supported by three yellow pine scantlings (3 inches × 1½ inches) running the length of the tank. These are supported by a frame formed of steel shapes. The cover *S*, provided with steam vents and an opening for the insertion of a thermometer *T*, is made of two sheets of copper, separated by a one-inch layer of hair felt, and fits tightly into the inner tank. The cover is supported and counterbalanced by means of the weights and pulley *W*, *P*, attached to the upper frame.

Both tanks are filled with water to the heights shown, the levels being maintained by bottles *B*, which automatically supply the loss due to evaporation or other causes. The inner tank is provided with two sets of shelves of tinned copper wire cloth with a one-inch mesh, supported by heavy copper angles; the lower shelf is always submerged and covers the whole area of the tank, while the upper shelf covers one-half this area and is always in the stream.

The tanks are heated by means of a copper coil supplied with

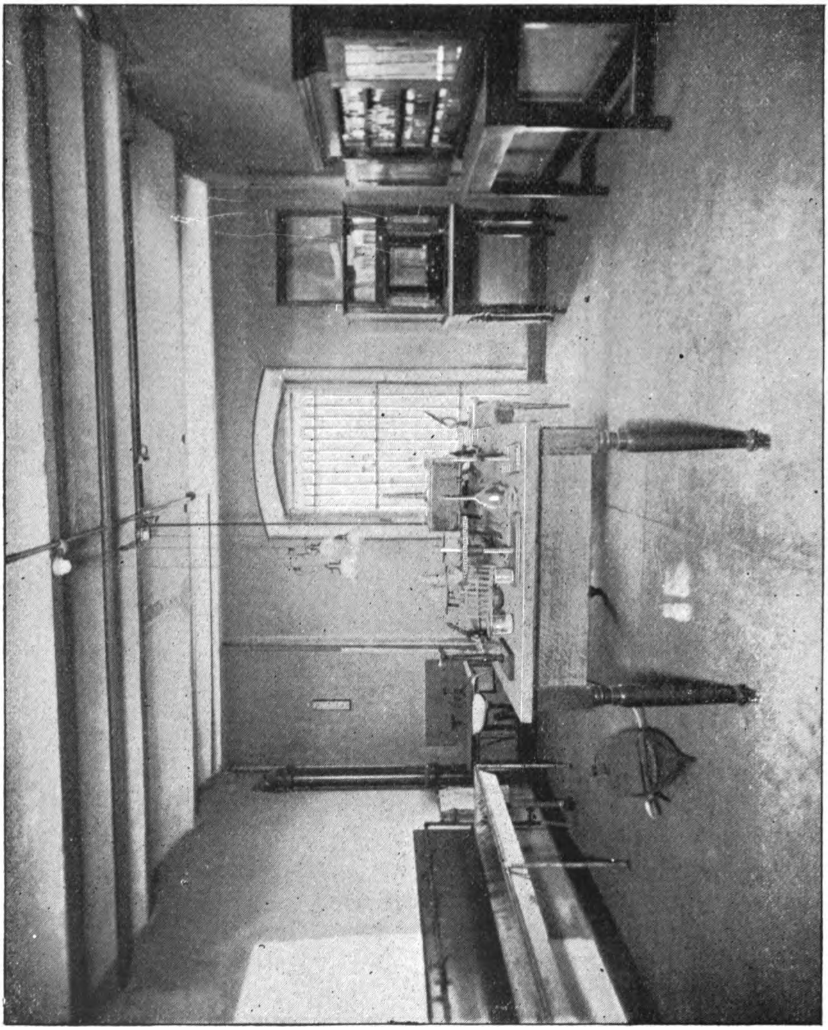


FIG. 17.—VIEW OF THE CHEMICAL LABORATORY.

steam, at about 80 pounds pressure, from a one-inch pipe. The water in the tanks (about 30 gallons) can be raised to boiling in about 3 minutes. The temperature of the water in the inner tank is controlled by means of a regulator, which can be set and constantly maintains the water in the tank at any desired temperature between 100° and 212° F. Cements are placed in hot water maintained at various temperatures for different lengths of time, and the results obtained are being carefully studied.

TENSILE STRENGTH.—Briquettes are broken at regular stated periods, each sample being tested for tensile strength, both neat and with standard proportions of sand, for 24 hours, 7 and 28 days. Additional briquettes are made, and are systematically distributed for breaking at intervals of 2, 3, 4, 6, 12, 18 months, 2, 3, 4, and 5 years.

For this purpose two books are kept, distributing book and a diary. The briquettes to be broken at longer intervals than 28 days are distributed in the former of these books. Each brand of cement occupies a page of this book, which is divided into columns, running up and down, and across each page; the former columns have headings appropriate for the various compositions (neat, 1 to 1, 1 to 2, etc.), whether made in Laboratory or on work, and method of preservation, etc.; the cross columns are headed 2, 3, 4, 6, 13, 18 months, 2, 3, 4, and 5 years.

The first entry is made in the appropriate vertical column in the cross column headed 2 months; the next entry of the same brand and composition, etc., is made opposite the 3-months column, and so on consecutively until the entire series of long-time tests up to five years has been recorded, then the entries begin again under the 2-months column. In this manner is obtained a systematic and equal distribution of briquettes to be broken at longer periods of time than 28 days.

In the Diary is entered under the proper date on which the briquettes are scheduled to be broken, the sample number, the number of the briquettes, and the hour, thus:

Oct. 3d, 1896.

2960	5	4.30.
321	5	2.50.
1610	5	1.00.

That is, five neat briquettes, each of samples 2960, 321, and 1610, are to be broken October 3d, 1896, at 4.30, 2.50, and 1.00 o'clock, respectively. By this means it is readily known what briquettes are to be broken each day. As a rule, the average results of three briquettes are taken as the tensile strength; in important tests, however, the average of five briquettes is taken.

Testing Machines.—For determining the tensile strength, the Laboratory possesses two Cement Testing Machines, each of 1,000 pounds capacity. These types of lever machines are two well known to merit special description.

Plans have been prepared for an entirely automatic cement testing machine of 2,000 pounds capacity based on a different principle, in which it is hoped that the faults of the present types of testing machines will be corrected. I hope to be able to describe to the club at some future time both this machine and the automatic sieving device.

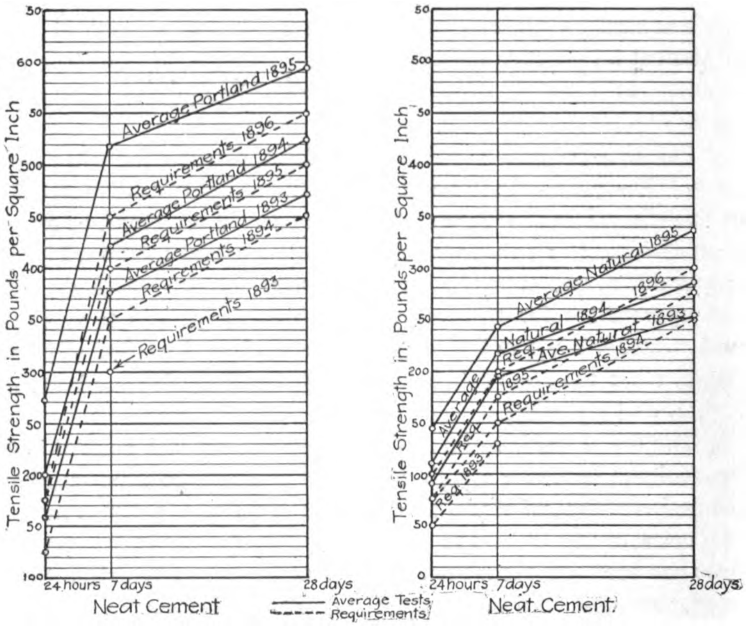


FIG. 18.—AVERAGE TESTS AND REQUIREMENTS.

CONCLUSION.—A great deal of attention is paid to the results of the tests of mortar taken from a mixing-box. The briquettes are made from the actual mortar on the work (1) as soon as mixed, and (2) just before it goes into the work. Experience has shown this to be one of the best aids in judging the actual merits of any brand of cement. Concrete tubes are also made on the work, and their weight per cubic foot and crushing strength is determined, the crushing strength giving an excellent idea of the adhesiveness of any brand of cement.

All cements are from time to time submitted to a chemical analysis. For this purpose the chemical laboratory (Figs. 12, 16, and 17) has been equipped with every facility for making complete chemical analyses. The detail apparatus is such as will be found in any well equipped laboratory, and does not require further description.

In addition to the regular tests, a great deal of experimental work is being carried on. Among the many studies may be mentioned the strength of cement in air, in hot water, mixed with various adulterants, and with various proportions of different sands.

Besides the standard sand the laboratory is provided with German normal and various kinds of natural sands.

The temperature of the laboratories is usually between 60° and 70° F. It is never permitted to fall below 60° F.; this being regulated by steam heat. In summer the windows are kept closed, and the temperature rarely rises above 80° F.

At the end of each year the results of the year's tests are averaged, each brand of cement being rated according to this average. The requirements of the specifications for the ensuing year being fixed in accordance with these results. The gradual increase in the average tests and requirements each year is well illustrated by the diagrams Fig. 18.

While the city requirements are to-day higher than those of any other city, nevertheless they are considerably less than the average results of the tests for the year 1895. This general increase in the requirements can be ascribed to three causes: increased skill in testing; gradual weeding out of inferior brands of cement, and to the improvements in the quality of the cement, due to the improvements in the process of manufacture.

The city of Philadelphia, as a direct result of maintaining this laboratory, is using cement from 30 to 50 per cent. stronger, and at a cost of from 20 to 40 cents per barrel less than it was in 1892. The city consumes approximately each year about 100,000 barrels of natural cement, and 30,000 barrels of Portland cement. It can be safely assumed on the basis of the prices prevalent in 1892 (when the laboratory was permanently established), and those prevalent to-day, that the city has saved in the last four years over $70,000. The cost of maintenance, exclusive of salary during this time, has been less than $500 per year. In other words, the city has saved $70,000, at a cost of less than 10 per cent. by the maintenance of this laboratory.

In closing, I wish to state that the successful development of this laboratory has, in a great measure, been due to the energetic support given to it by Mr. George S. Webster, Chief Engineer, Bureau of Surveys.

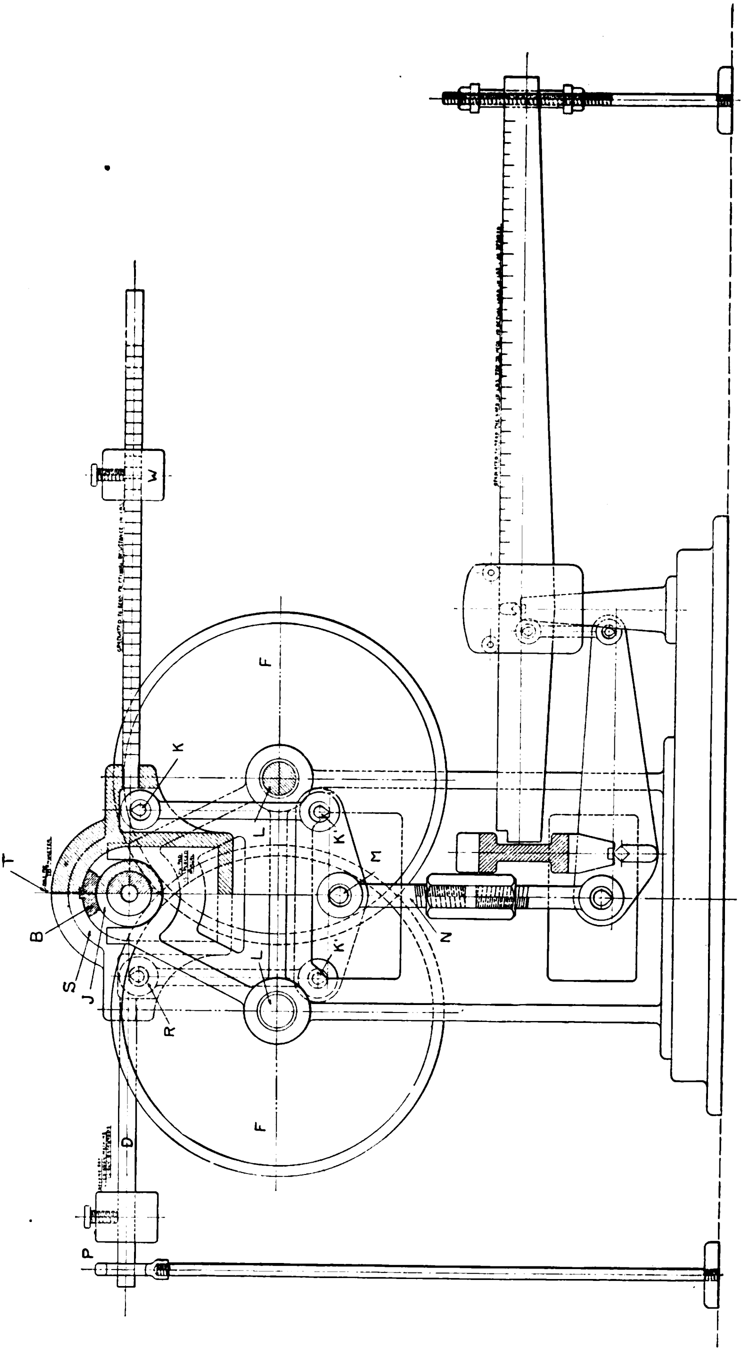
FIGURING BOILER STRENGTH.—Whenever the United States Government sends an engineer to figure the strain to which any boiler may be subjected while at work, the inspector uses a formula much different from that employed by the insurance inspectors. The government makes no account of riveted seams; the insurance inspector allows from 56 to 70 or 84 per cent., accordingly as a seam is single or double riveted or is fastened with a strap joint. Apparently the government inspection allows a greater steam pressure per square inch than does the insurance inspector, and in some cases where I have carefully figured the riveted seams, I have found that government inspections allow boilers to run with a factor of safety somewhat less than 4 per cent. This would not be allowed by any reputable boiler insurance company. The consideration of this matter demonstrates that in figuring the strength any steam boiler it will not do to take 56 per cent. of the shell for the strength of a single riveted seam, without figuring the strength of that seam. A properly devised seam will give more than 56 per cent.; that figure is a fair average, as single riveted seams go, but in order to be exact, the pitch and diameter of the rivets must be obtained, and with the thickness of plate used in shell, the percentage of plate strength left between the rivet holes can be very exactly determined. In this and only by this way can the actual safe working strain of any boiler be ascertained.—*Tradesman.*

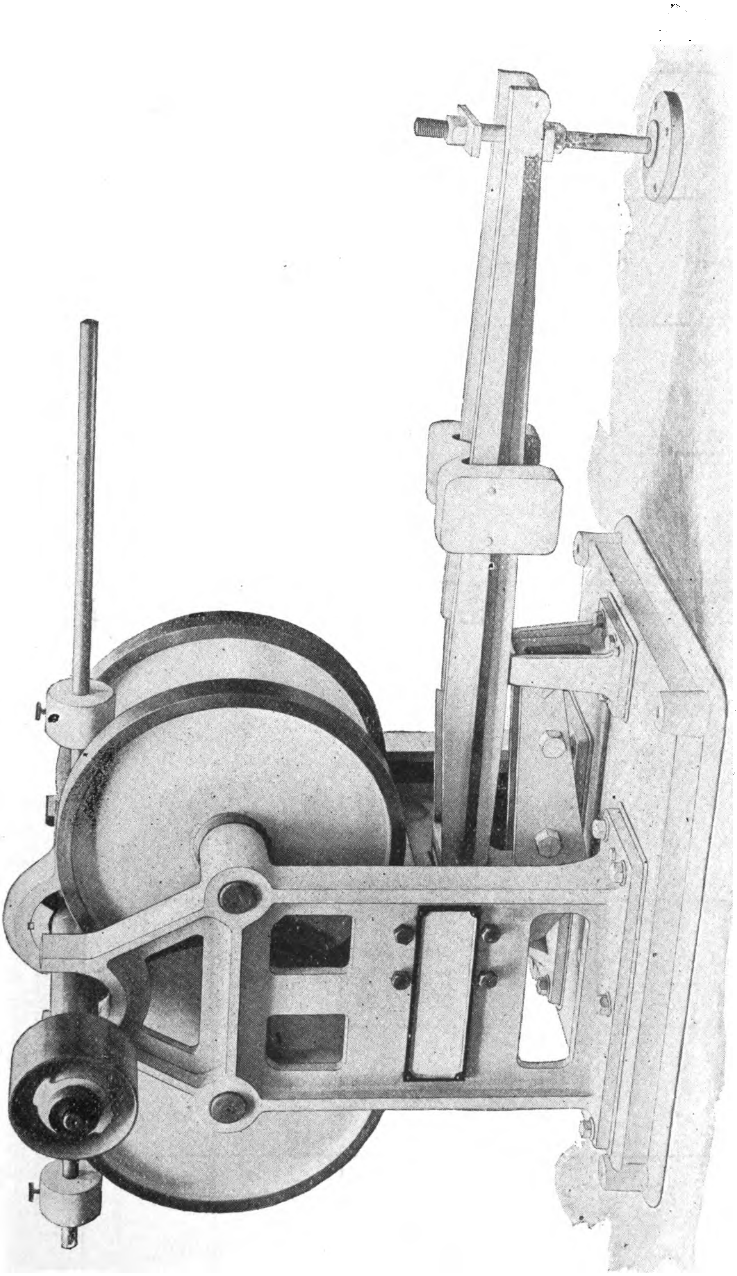
THE ENGINEERING DEPARTMENT OF THE YORKSHIRE COLLEGE, LEEDS.

EXPERIMENTS IN THE ENGINEERING LABORATORY—FRICTION TESTING MACHINE.

FOR some years past Professor Goodman's name has been connected with experiments on the friction of axles and lubrication. Most of his work has been done on a small "Tower" machine, on which a load of about one ton could be placed on the bearing. Such a load was, however, found to be much too small for many purposes, and, moreover, the carrying out of tests in which the load has to be frequently varied is extremely inconvenient when dead loads have to be lifted up and down by hand. This consideration led Professor Goodman to design a friction-testing machine on entirely new lines, in which the load is applied by a system of levers, and yet the bearing stirrup is perfectly free as regards rotation, which is necessary in order to allow of the friction being measured. It is a perfectly simple matter to load a bearing with a lever, but it is a very different matter to load it in such a manner that the friction can be measured.

The diagram and illustrations will make the general arrangement of the machine quite clear. The journal J, on which the bearing B rests, is a 6-inch steel collar shrunk on to a 4-inch hollow axle. The bearing under test fits into the stirrup S, which is provided with two knife-edges K and R, which are in line with the centre of the shaft and exactly equidistant from it; by slightly rotating the knife-edge R by means of the screw and lever A they can be brought into exact adjustment. The two links L, L are suspended from these knife-edges, and are attached to two similar knife-edges K_1, K_1 in the crosshead below. From a third knife-edge M in the middle of this crosshead the screwed link N is suspended, the lower end of which is attached to the system of levers as shown, the three knife-edges in the crosshead, as in the case of the three centres in the stirrup, being in one line, hence the crosshead and stirrup are perfectly free to rotate about their own centres, and the pull on the two links has no tendency whatever to cause rotation of the stirrup. The friction on the bear-


T
B
S
J
R
D
P
W
K
K'
L
M
N
F



GOODMAN FRICTION MACHINE.

Fig. 30.

OIL TESTS.

The curves show how the temperature rises & the friction diminishes with the time

Pressure 1000 lbs. per Sq. in.

Surface Speed 314 Revs. per minute.

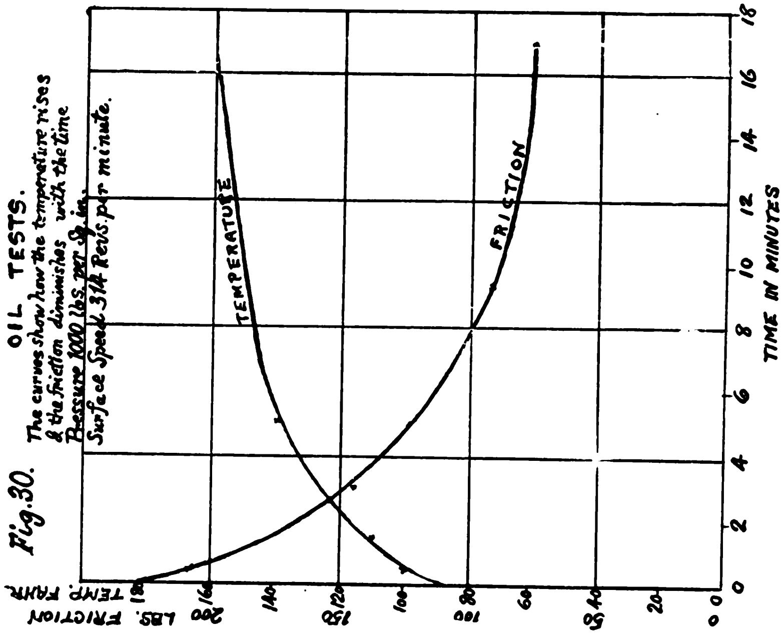


Fig. 29.

Curve showing the effect of Temperature on the Friction.

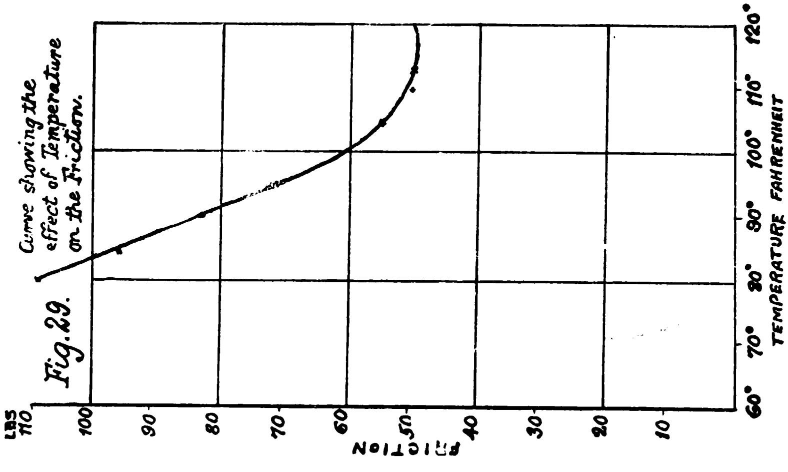


Fig. 28. Surface Speed 314 Feet per minute. Temperature 120 Fahr.

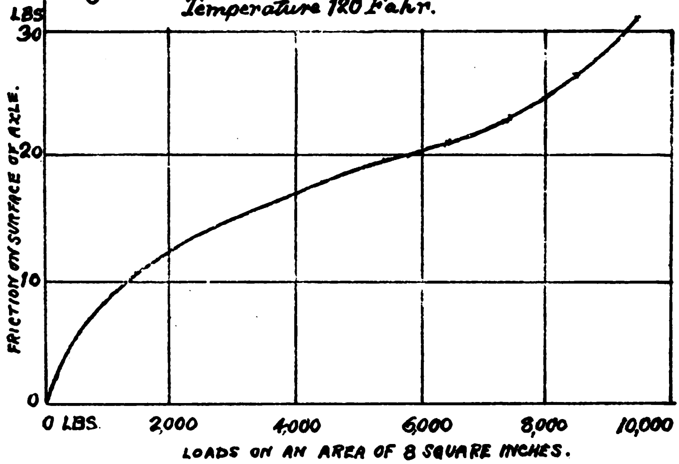
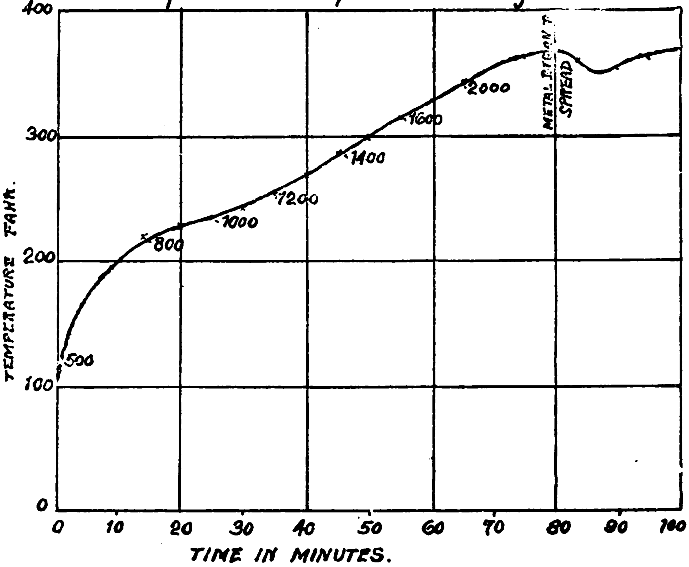


Fig. 26 Surface Speed 2094 feet per minute The figures on the curve represent the pressure in lbs. Sq. In. on the bearing.



ing is measured by the moment of the weight W about the centre of the axle. When the machine is running the friction on the bearing tends to carry the stirrup and arm round out of the horizontal; it is brought back to the horizontal position by adjusting the position of the weight W; the arm C is graduated to read off direct the frictional resistance on the surface of the axle. In order to compensate for any error in the adjustment of the stirrup the machine is made to run in both directions for each test, the mean of the two friction readings being taken. To avoid the use of the two graduated arms and movable weights a dead-weight is hung on the balance-weight arm D when the machine is running backward; the zero position of the weight W is then at the reverse end of the scale. A small pointer P attached to the balance-weight arm serves to indicate when the stirrup arm is perfectly horizontal, which it is necessary to attend to when taking a reading of the friction. A thermometer T is placed in a hole in the bearing with its bulb about ⅛ inch from the surface, in order to register the temperature of the bearing; a little oil placed in this hole serves to make contact between the bulb and the metal. Mercury is better, but it amalgamates with the metal and damages the bearing. A water supply E is laid on so that either hot or cold water can be circulated through the centre of the axle in order to keep the temperature of the bearing the same throughout a test. This is, of course, a purely artificial method of cooling, but for testing purposes it is absolutely essential that only two quantities shall vary in any one experiment. Hence, when finding the variation of the friction with varying loads the temperature must be kept constant; in some cases a variation of 10° F. in the temperature will make 100 per cent. error in the friction results.

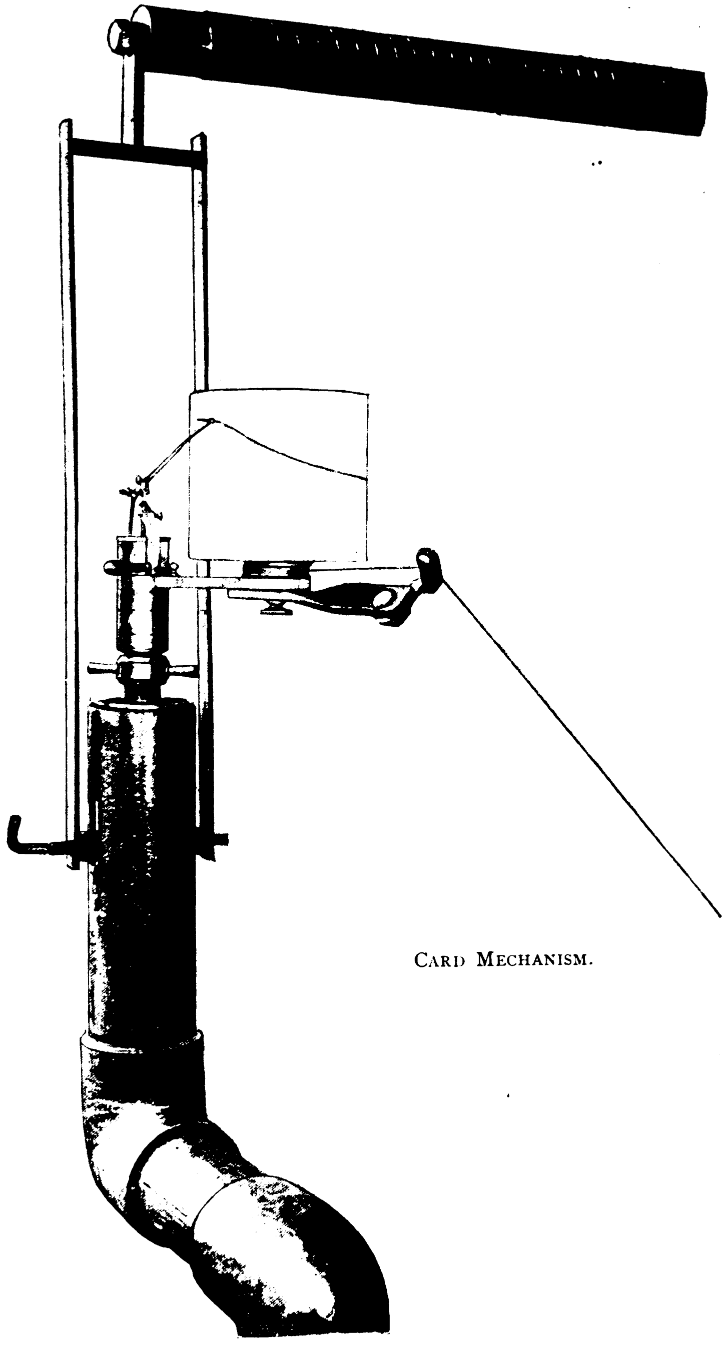
The main axle of the machine is mounted on large massive friction rollers F, not to reduce the friction, but to prevent any local heating of the machine from affecting the temperature of the test axle when temperature tests are being made. In order to keep the test axle in its proper position longitudinally a ball-collar bearing is used, a ball bearing being chosen on account of its security from heating. The test bearing is lubricated by either an oil bath or a meagrely oiled pad; in the latter case the pad is accurately weighed and the quantity of oil also weighed, and the pad pressed evenly against the axle by means of a spring. Very great care has to be taken to insure that the lubrication is precisely the same in all cases.

The machine is usually driven by a belt when low-speed tests are being made, but for high speeds an electric motor is always used. The motor is constructed to run at 2,000 revolutions per minute—*i. e.*, 3,140 feet surface speed on the bearing, but it is very rarely necessary to run it at more than 1,500 revolutions per minute, for only the highest quality of anti-friction metals will stand such speeds under heavy loads. A sulphuric acid and water resistance is introduced into the main circuit for regulating the speed. With a little care in the adjustment the motor can be kept running for hours together without varying more than 10 revolutions on either side of the mean when running at 1,500 per minute. The maximum load that can be applied by the lever system is 10 tons, but it can be easily increased if it should ever be required.

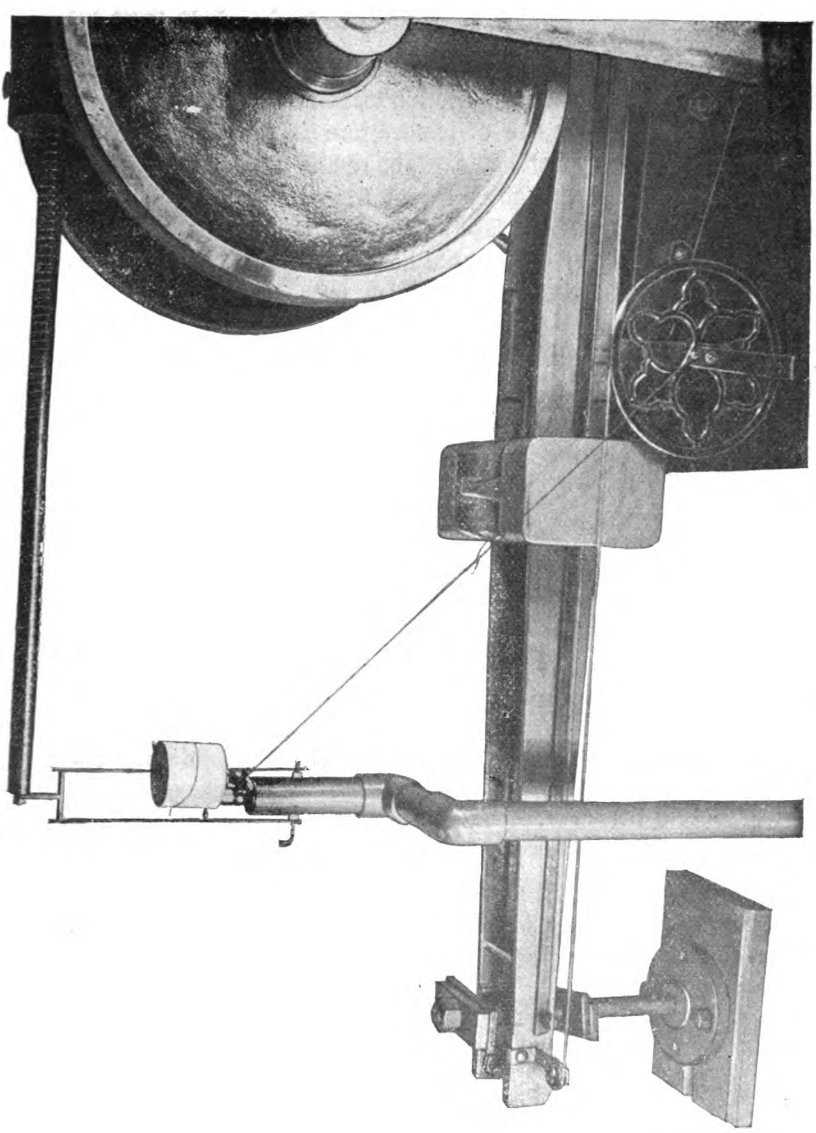
For the bearing itself special cast-iron shells are used, into which the antifriction alloy is poured; the bearings are thereby made to exactly the same area. After casting, the bearings are bored out in a special machine made for the purpose, which makes them all of exactly the same thickness and brings the wearing surface dead true with the outside of the shell. A standard drill of special construction is used for drilling the thermometer hole, so that the bulb is always at the same distance from the wearing surface. The temperature at which the metal is poured is measured by a Le Chatelier pyrometer. Experiments are now proceeding to show the effects of pouring the metal at too high or too low a temperature.

After boring out the bearing it is put in the machine and the electric motor coupled up; then after a few hours' running at a high speed and a load of about 1,000 pounds per square inch, the bearing is found to have a beautiful wearing surface all over; it is, however, not in a fit state to test until it has been allowed to run for about two days at approximately the same speed, pressure, and temperature at which it will be tested. Careful observations of the friction have to be taken at intervals to see whether it is constant or not. If found to be gradually improving, the machine is allowed to run until the friction does become constant. Professor Goodman, after about thirteen years' experience in friction tests, says that he is constantly learning fresh points, and knows of no other experimental work that is so extremely difficult to satisfactorily carry out.

Amongst other friction researches that Professor Goodman now has in hand is a long series of antifriction alloys, the body of the metal being the same in all cases, the only difference in the alloys being ¼ of 1 per cent.—*i. e.*, one part in 400, of other metals.



CARD MECHANISM.



CARD MECHANISM SHOWING ATTACHMENT TO POISE.

Small as this quantity may appear, yet it makes a huge difference in the friction; in some cases the friction is more than twice as high as in others, but further details of the tests must be left over until the research is complete.

We give in Figs. 26 to 30 a few typical curves showing the sort of results that are obtained on a friction machine of this kind. Tests which simply measure the rise of temperature as the time proceeds are, however, extremely unreliable. The results obtained on a day when the air is moist are totally different from those obtained when the air is dry. They are, however, often resorted to by novices as being the easiest to carry out, but old hands fight shy of them, knowing the many pitfalls that surround such tests. "Fools will rush where," etc.

We understand that an automatic recorder is now being fitted to the machine just described, in order to study the effects of sudden loads on bearings, such as occur in connecting-rods, rocking shafts, etc.—*London Engineering.*

GENERAL SPECIFICATION FOR STRUCTURAL STEEL.

With Explanatory and Descriptive Notes by Stowell & Cunningham, Civil Engineers, Albany, N. Y.

Kinds of Steel.—1. Steel shall be made by the following processes:

Acid Bessemer,
Acid Open Hearth,
Basic Open Hearth.

Grades of Steel.—2. Steel shall be divided into three standard grades, two intermediate grades, and two extreme grades, and named as follows:

Standard Grades—
    Soft, Medium, and Hard.
Intermediate Grades—
    Soft-Medium and Medium-Hard.
Extreme Grades—
    Very Soft and Very Hard.

The various grades of steel shall possess the physical properties set forth in the following table when tested in tension and in bending:

TABLE OF PHYSICAL REQUIREMENTS.

GRADE.	Conventional Designation.	Minimum and Maximum Ultimate Strength in pounds per square inch.	A Minimum per cent. of Elongation after Fracture on an Original Length of 8 inches.		A minimum per cent. of Reduction of Area at Fracture.		To Bend Without Rupture						
							Cold.		At a Red Heat.		When Quenched in Water from a Dark Red Heat.		
			For Universal Plates, Shapes, and Bars not over ¾ inch thick.	For Sheared Plates not over ¾-inch thick.	For Universal Plates, Shapes, and Bars not over ¾-inch thick.	For Sheared Plates not over ¾-inch thick.	Amount of Bending in Degrees.	Diameter of Inside Curve in Thickness of Test-piece.	Amount of Bending in Degrees.	Diameter of Inside Curve in Thickness of Test-piece.	Amount of Bending in Degrees.	Diameter of Inside Curve in Thickness of Test-piece.	Temperature of Water in Degrees Fhr.
Very Soft, . . .	V. S.	50,000 and under.	25	24	50	48	180	0	180	0	180	0	60
Soft, ...	S.	50,000 to 60,000.	25	24	50	48	180	0	180	0	180	0	70
Soft-Medium, .	S. M.	55,000 to 65,000.	25	24	50	48	180	0	180	0	180	1	80
Medium, . . .	M.	60,000 to 70,000.	24	22	48	44	180	1	180	0	180	2	80
Medium-Hard,	M H	65,000 to 75,000.	22	20	40	35	180	1½	180	0	180	3	80
Hard, ...	H.	70,000 to 80,000.	20	18	35	30	180	3	180	0	90	3	80
Very Hard, . .	V. H.	80,000 and over.	15	12	25	20	90	3	180	0	Not required.		

Elastic Limit.—3. All grades of steel shall have a minimum elastic limit of one-half the ultimate strength.

Allowance for Thickness.—4. For each one-eighth inch increase in thickness over three-quarter inches, a reduction of the percentages of elongation and reduced area will be allowed as follows:

One-half per cent. in elongation,
One per cent. in reduction of area,

to a maximum allowance of five per cent. in elongation and ten per cent. in reduction of area.

Physical Tests.—5. The physical properties of the various grades of steel shall be determined upon test-pieces cut from the finished material, the location, size, and shape of which shall be satisfactory to the engineer in charge.

Number of Physical Tests.—6. There shall be made one tension test, and one cold, one hot, and one quenched bending test from every cast of steel, and for every 20,000 pounds or fraction thereof in a cast.

Character of Fracture.—7. The fractures of tension tests shall be characteristic of the grade of steel tested, and shall be free from indications of injurious heat treatment or injurious or insufficient working.

Qualities of Steel.—8. Each *kind* of steel shall be divided into three standard qualities, and named as follows:

Ordinary,
Good,
Superior,

or a quality may be specified known as Special.

The qualities of the various grades shall be determined by the amount of Phosphorus and Sulphur contained, which shall not exceed the fractions of one per cent. set forth in the following table:

TABLE OF QUALITIES.

Acid Open Hearth.			Basic Open Hearth.			Acid Bessemer.		
Quality.	Phos.	Sul.	Quality.	Phos.	Sul.	Quality.	Phos.	Sul.
Ordinary, .	.10	.05	Ordinary, .	.06	.04	Ordinary, .	.10	.05
Good,	.08	.04	Good . . .	.04	.03	Good, . .	.08	.04
Superior, .	.06	.03	Superior, .	.02	.02	Superior, .	.06	.03

The Special Quality shall not contain more than the fractions of one per cent. set forth in the following table:

Kind of Steel.	Elements.									
	P.	S.	Mn.	Si.	Cu.					

Chemical Tests.—9. The quality of the various kinds and grades of steel shall be demonstrated by an analysis made upon small samples selected from the molten steel when cast.

Analysis of samples taken from any part of the finished material shall not show an increase in the specified limit of elements of more than fifty per cent.

Number of Chemical Tests.—10. There shall be made one small sample analysis and one finished material analysis for the specified elements of each cast of steel.

Additional Tests.—11. Should a reasonable doubt exist as to the kind, grade, quality, or uniformity of steel furnished, the engineer in charge may order additional physical and chemical tests before final acceptance.

Inspection of Manufacture.—12. Should the engineer in charge so elect, he may inspect the entire process of manufacture, from the raw materials to the finished product.

Finished Material.—13. Finished material shall not vary more than two and one-half per cent. from calculated weight; it shall be made according to ordered sections and shall be free from defects and of a workmanlike finish. All finished material shall be indelibly marked in a manner identifying it with the cast of steel from which it was made.

Eye Bar Tests.—14. Full-sized eye bar tests will be required to break in the body of the bar. They will be allowed a reduction of ultimate strength of 5,000 pounds per square inch below the minimum ultimate of the grade of steel from which they are made, and shall give an elongation in the body of the bar of one-half that required for the same grade of steel in specimen tests under three-quarter inch thickness. The elongation shall be measured in twenty feet, including the fracture, where the body of the bar shall exceed that length. The fractures shall be subject to the requirements of fractures for tension tests.

NOTES.

Introductory.—The chief defect of almost all modern specifications for structural steel lies in the fact that properties only are specified and not quality. By the properties of steel we mean those physical or chemical characteristics which can be definitely determined by the testing machine, the blacksmith's hammer, or by chemical analysis. By quality we mean that condition of internal structure which is indicated by the presence or absence of blow-holes, sponginess, etc., and by the degree of homogeneity of the metal. The properties of steel are absolute; its quality, comparative. By its properties we are able to determine the strength of the pieces upon which we make experiments and their suitability for the use to which we intend to put the metal. By its quality we can judge whether all the rest of the steel, upon which experiments have not been and cannot be made, is likely to prove equally as strong and suitable as the selected samples and to endure for any length of time the work which we intend to impose upon it. The chemical composition of steel is an important function of both its properties and its quality. Without a sound constitution to start with no steel can be reliable. Skillful manipulation may conceal to some extent the symptoms of a bad constitution, but cannot effect a cure. The method of manufacture and the processes used in furnace work, have an important bearing upon the *quality* of steel and comparatively little effect upon its *properties.* Rolling-mill manipulation *may* affect quality, as by unskillful heat treatment a constitution originally good may be weakened or destroyed, but the process of rolling in itself does not affect the quality of steel, though it has a very decided effect upon its properties. A piece of steel may show excellent ultimate strength, elastic limit, reduction, and elongation, and still be of a very poor quality, and conversely, quality of a high order may exist with properties which would render a steel entirely unfit for the use for which it is desired. It is only by securing the requisite standard of both properties and quality that we can feel assured of the safety and endurance of any steel structure. To the neglect of one or the other of these considerations (but almost always of the quality) may be attributed a good many failures of steel structures which seemed most mysterious; and failure to recognize or understand the importance of both considerations has caused in the past and still continues to cause many users of metal to look with distrust on any steel for structural purposes.

Most specifications for structural steel prescribe physical tests alone; it being erroneously assumed that metal which in test-pieces shows good physical results must be reliable and lasting. A very few specifications recognize the importance of quality, but these specifications are confined to steel of definite and special kinds. It is believed that the following specifications are the first wherein quality, as distinct from and independent of properties, is recognized and provided for in all kinds of steel adapted to all structural purposes.

The physical requirements in these specifications are purposely made more moderate than in many others. The possibilities of steel making are well known and it is useless to make specifications outside of them. Very high specified limits for physical tests do not always bring any better steel, but only make it necessary to carefully select the places from which the test-pieces are cut in order to get the desired results. Sometimes, especially if these limits are not well "balanced" among themselves, they are a temptation to the manufacturer to put special treatment on the test-pieces. They lead the purchaser, too, to a false sense of security in his structure, giving him the idea that the whole of the metal is of the character which the steel-maker sometimes knows is only possessed by selected or possibly specially treated test-pieces. It is believed to be better to specify such physical limits as the poorest part of a piece of steel should show and which can be obtained without undue expense or extraordinary manipulation by any skillful maker. And this, of course, carries the inference that the purchaser or his inspector possesses sufficient knowledge of steel making to select his samples for testing from the places which will give the poorest results. The strength of a structure like that of a chain, is the strength of its weakest link; and there would seem to be little use in making experiments on the strongest links while we do not know what the weakest one will bear. Some specifications are in use wherein the limits are so fixed that it is absolutely necessary to carefully select the best places in order to get results fulfilling the requirements, because steel cannot be made whose worst parts will satisfy the conditions.

There are natural phenomena incident to the manufacture of steel which tend to make certain portions of the ingot (and the steel rolled therefrom) poorer than the rest. The most important of these is segregation—which means the tendency of certain chemical constituents to separate from the others and gather by themselves during the process of cooling from a molten condition, so that in a solid ingot the chemical elements are by no means uniformly distributed. Unfortunately the segregating tendency is highly developed in the case of phosphorus, which is at the same time the most intense element in its influence toward making the steel brittle, or "cold short." Consequently, while an analysis of a sample from the molten metal at the time of casting will give the *average* amount of the different constituents of the steel, it is quite certain that some parts of the ingot will contain more and some parts less certain constituents than the average, with a corresponding variation in the quality and properties of the finished steel. At the most highly segregated points the phosphorus element may exist in double the amount found in the least segregated portions. It is useless to specify against this natural phenomenon and unwise to ignore it. It is better to recognize it and provide for it, as is done in these specifications, setting such limits as will not be impracticable or too onerous for the manufacturer on the one hand, or will allow segregation to become dangerously excessive on the other. By having an inspector of sufficient skill to select the most highly segregated spots for an analysis, the purchaser can be absolutely sure of knowing the worst possible conditions existing in his steel on account of segregation.

To those who are entirely unacquainted with the use of steel the question may arise, inasmuch as the working stress on a structure is always designed to be considerably less than the elastic limit (so called) of the material, why not use the harder grades of steel, having a high elastic limit, with a correspondingly high unit stress, and thus effect a considerable economy in weight? If it is safe to impose a unit stress of 10,000 pounds per square inch on a material whose elastic limit is say 25,000 pounds per square inch, why is it not equally safe and much more economical to use a unit stress of say 25,000 pounds and a material whose elastic limit is known to be not less than 40,000 pounds per square inch? The reason is because the harder grades of steel have a less extensibility *beyond* the elastic limit than the softer ones. Although the maximum stress on a member is always designed to be well within the elastic limit, probably no piece of metal which ever enters into a structure is not strained beyond this limit in *some portion*. The process of straightening, for instance, puts a "permanent set" in some portions of a bar, otherwise it would not be straightened, while punching and shearing always strain the metal beyond the elastic limit, in the immediate vicinity of the parts operated upon. Now in the softer grades of steel such local deformation beyond the elastic limit can be made without serious injury to the bar as a whole; but with the harder grades, by reason of their less extensibility beyond the elastic limit, it is liable to produce fractures. Such fractures may be of microscopic size at first, but, inasmuch as steel is essentially a non-fibrous substance, fractures which, in iron, for instance, could not extend and produce rupture beyond the fibers in which they originate, in steel are likely to increase in extent indefinitely under repeated applications of stress. Mr. T. Claxton Fidler says: "Although a strong steel may offer a very high resistance to a steady and uniformly distributed stress, yet the *work* required to tear it asunder may be considerably less in the case of milder and tougher metal, while at the same time the latter kinds of material are much more capable of adapting themselves to those local inequalities of stress which are almost certain to arise either from local inequalities of modulus or from the form of structural details." Local inequalities in modulus may be reduced to a minimum by care in securing the proper *kind* and *quality* of steel, but local inequalities of stress due to the form of structural details can only be obviated by changing the details. The evil effects of local deformation beyond the elastic limit may be eliminated by cutting away all the metal so injured. But the extra cost of this operation frequently overbalances the saving from the use of a strong steel at a high unit stress while at the same time one feels safer on the whole in using a metal which is not liable to serious injury from ordinary treatment, than in using one which is knowingly injured and afterward subjected to remedial treatment to remove the effects of such injury.

The Specification.—These specifications are intended for the convenience of the users of steel, whereby any grade of steel desired can be readily provided for, from the commonest kind to the finest grades of boiler plate and forging steel. In cases where it may be desirable, the *kind* and *quality* of steel may be left blank and the grade only specified; or if the ultimate strength becomes a minor consideration, two interlapping grades may be provided for, as "Soft" and "Soft Medium." By means of the "Special Quality" a steel superior or inferior to the standard can be definitely specified.

Kinds of Steel.—The kinds of steel definitely provided for are those processes by which the great bulk of structural steel is made in the United States. Other more or less well-known processes are in use and if desired can be specified as provided for.

Grades of Steel.—The seven grades of steel specified will cover every class that is needed for structural material.

The selection of a grade of steel for any work should be governed by the conditions of shop manufacture and the intended use of the structure into which the steel is to be put. In general, the softer the steel the more abuse it will stand without dangerously affecting its properties. The abuse to which steel is subjected is of two kinds—legitimate and illegitimate. Legitimate abuse consists of the shearing, punching, straightening, bending, and distorting, either hot or cold, with or without subsequent annealing, to which the steel is necessarily subjected in the mills and shops during manufacture. Illegitimate abuse is the drifting of poorly matched holes, the gouging of blind holes, the cutting off hot of surplus material which should be removed by machining, the "stretching" of material which is too short, the over-heating of rivets, eye-bar heads, and other forgings, and the thousand and one other things used as "short cuts" to an end, or by workmen to cover up their blunders.

As the harder steels are approached, the abuse must be curtailed or remedied. For legitimate abuses, well reamed or drilled holes are substituted for punched holes; sheared edges are planed off; material bent hot or cold is thoroughly annealed; forgings are worked at a lower heat and carefully kept from sudden cooling. The illegitimate abuses should be prevented, as far as possible, by thorough and competent supervision and the imposition of severe penalties when detected. The combination of a soft grade with a good quality will produce the most satisfactory results in general practice.

The variation in ultimate strength for all grades, except the extremes, has been made 10,000 pounds. In the extreme grades, softness in one case and hardness in the other are the main considerations, and, therefore, but one limit has been imposed.

The variations in ultimate strength imposed in specifications, within reasonable limits, are purely a matter of individual taste. The variation most commonly allowed is 8,000 pounds, but numerous exceptions to this may be found in which the variations range from 4,000 pounds to 14,000 pounds. The specifications for hull material used by the United States Navy has only one limit for ultimate strength—a lower one—and under this specification have been made large quantities of most excellent materials.

The ultimate strength of steel depends fundamentally upon the percentage of elements contained—the principal hardener being carbon. With these as a base, the ultimate strength may be increased or diminished from normal conditions by varying the heat treatment and manner and amount of work. The specifying of narrow limits for ultimate strength, in order to secure a uniform steel, may therefore result in securing a metal that is decidedly non-uniform in other respects.

Some of the uses for which the different grades of steel are adapted are given below.

Very Soft.—For work subject to considerable distortion in manufacture and used under a low intensity of stress; very soft rivets; to replace iron subject to low intensity of stress.

Soft.—To replace iron; tension and compression members; for punched work, without subsequent reaming; rivets; eye bars; rolled pins; tank plate; web plates.

Hard.—Drilled compression members; bearing surfaces; forged pins.

Very Hard.—Machinery; bearing surfaces.

Elongation and Reduction.—The elongations and reductions of area are moderate for each grade and should be readily met by standard tests cut from *any* part of the material, provided it has received proper heat treatment and work. For test cuts in the ordinary manner—namely, from the most favorable locations—these specified results will be exceeded.

It will be noted that for the softer grades the reduction is numerically twice the elongation, and that for the higher grades it becomes less. These ratios are in accordance with the nature of the material.

When ordinary thicknesses are exceeded, the finishing temperature and amount of work are no longer normal, and the greater the variation in thickness the greater will be the consequent variation in elongation and reduction due to these causes. A reasonable limited variation has been provided for these cases. In exceedingly thin material there may also be a falling off in elongation, as also in forged material, but it is impossible to make provision for every case that may arise, and the generality have been provided for.

The difference in elongation and reduction between sheared plates and other material of the same grade is provided, on account of the different manner in which they are rolled.

The specifying of exceedingly severe requirements for elongation and reduction does not necessarily secure a better quality of steel than fair requirements in this respect. It does, however, limit the location from which tests are cut, and may even necessitate unusual treatment of the material from which the tests are taken. The gain, consequently, may be negative.

Bends.—The cold, hot, and quenched bends are moderate, and should be met by tests cut from *any* part of the finished material, provided the *physical* treatment has been correct and the *chemical* composition is good. Cold bends develop excess of cold shortening elements. Hot bends develop excess of hot shortening elements. Quenched bends develop excess of hardening elements, otherwise concealed by hot finishing or annealing.

Elastic Limit.—Elastic limits are sometimes left out of steel specifications altogether; in other cases the elastic limit is required to be a certain percentage of the ultimate strength, and the most common case of all is where a certain fixed minimum elastic limit is specified. The fixed elastic limit is probably a survival of the adaptation of iron specifications to steel during its early use in structural work. The variable elastic limit is entirely logical, but not more so than its omission, unless certain definite objects are in view which it is not desired to provide for in a perfectly definite manner.

The elastic limit herein provided for of one-half the ultimate strength is a safe minimum limit for all kinds, grades, and qualities of *well worked* steel. In steel castings, which are not worked at all, and in large sections which only receive work enough to bring them to form, the elastic limit will be sometimes found to be somewhat less than one-half the ultimate strength.

Elastic limits, as ordinarily determined in testing machines, are in reality the "breaking down" points of the test specimens, and are beyond the point of true elastic limit. The elastic limit is reached when a material receives sufficient stress to distort it beyond recovery to its original form. There may be several such points in steel, and some investigators claim that every stress, however slight, produces "a permanent set" in steel. When steel has received a sufficient stress to destroy *all* of its *elasticity*, so that each additional increment of stress which is applied, whether great or small, increases the distortion, the final elastic limit has been passed and the material is no longer fit for use.

Physical Tests.—The finished condition is the point at which the user takes up the steel, and it is, therefore, from the finished material that the tests should be taken. Preliminary tests are a guide to the manufacturer and an aid in securing certain definite results in the finished material.

The location, size, and shape of test-pieces as used in general practice are a sufficiently accurate guide to the physical properties of steel as far as they can be demonstrated by ordinary tests. When common practice shows that the steel is not as specified, it is possible, by varying the conditions of the location, size, and shape, to make it appear otherwise than it really is. Varying the condition of tests by annealing or other special treatment also gives misleading results, as such tests do not represent the finished condition of the steel.

The number of tests provided, if selected with proper discrimination, will give a good indication of the value of the steel which they represent.

The appearance of the fracture of a tension test is a valuable guide to the condition of the steel. In the ordinary grades of structural steel which have received good heat treatment and work, the appearance known as "silky" occurs, which somewhat resembles in color that of a broken slate pencil. The form is described as "angular" or "cup," or may be a combination of the two forms, and is caused by the rupture of the test-pieces in the planes of shear which are developed under stress. As the harder grades of steel are approached the fracture has a tendency toward fine granulation and ultimately takes a fine granular form, also called "silky," and occurs in a plane at right angles to the axis of the test-piece.

Coarse granular or crystalline fractures may indicate too high or too long heating. Coarse, irregular, and open fractures, having an appearance like coke (described as "coky") may indicate insufficient work. Abnormal conditions of fracture are generally accompanied by abnormal conditions of elongation and reduction. When an abnormal fracture occurs it should first be ascertained whether it is not due to improper or insufficient machining of the test-piece, local flaws, or injurious local treatment.

Qualities of Steel.—The solid elements most commonly occurring in steel, besides its basis of iron, are carbon, phosphorus, sulphur, silicon, manganese, and copper. All elements have more or less of a tendency to produce hardness, that of phosphorus being the most intense.

The general effects of the above elements on steel may be briefly described as follows:

Carbon.—Carbon is the element depended upon for producing the various grades of hardness or rather strength in steel, and varies from .05 of one per cent. in softest grades to 1½ per cent. in the hardest. With increasing hardness comes increased brittleness and loss of ductility, but in a definite and well-known manner for carbon, which is attended with fewer other evils as a hardener than any other common element.

Phosphorus.—Phosphorus is an element which occurs almost universally in steel. It is undesirable, but in small amounts does not appear to exert any marked influence, while in larger amounts it makes steel "cold short" and treacherous under sudden shocks. Its cold shortening and treacherous effects are intensified at a low temperature. The effects of large amounts of phosphorus are not apparent in an ordinary tension test.

Sulphur.—Sulphur, like phosphorus, is an almost universal and always undesirable element in steel. In small amounts its effects are not marked. In large amounts it makes steel "red short" or unworkable in rolling or forging. When steel becomes cold the active effects of sulphur cease, but there is a dangerous point for this element at which steel may apparently roll or forge all right and still be filled with invisible defects which may cause its failure under stress.

Copper.—Copper, like sulphur, is a "red shortener," but its effects are not as intense as those of sulphur. It does not occur in all steel.

Silicon.—Silicon is also a "red shortener," in excessive amounts. The presence of silicon in steel assists in the production of sound ingots. In steel castings which do not require subsequent forging, silicon is added to secure soundness.

Manganese.—Manganese is added to steel as an antidote for the dangerous and undesirable elements, and has a neutralizing effect on their action. It also assists in the production of sound ingots. Excessive manganese is undesirable as it is productive of "cold shortness."

Besides these common elements which occur in steel there are sometimes added for special purposes nickel and aluminum.

Nickel.—Nickel is added in small quantities to produce a steel which combines the properties of hardness and toughness.

Aluminum.—Aluminum is added to steel in small quantities to produce sound ingots. When in excess it causes the ingots to "pipe" and produce a brittle steel.

The qualities of steel in these specifications have been based upon the phosphorus and sulphur content. This has been done because these are the most dangerous and undesirable elements in the steel and the ones which largely govern the price of the stock from which the steel is made. Three qualities for each kind of steel have been provided, which will be sufficient for almost any case that may arise.

Ordinary quality is suitable for structures not subject to impact or wide variations of stress, or where the result of a possible failure will not be serious.

Good quality is suitable for all ordinary structural purposes except tension members subject to wide or severe variations of stress.

Superior quality is suitable for eye bars, floor beam hangers and other tension members subject to impact or widely varying stress, for forgings, for boiler and other plates subject to severe shop usage, and generally for all purposes requiring the highest degree of excellence.

Where the standard qualities may not fit the case, provision has been made for a special quality which may be used for special forgings, welding steel, etc.

In fixing the limits for quality the peculiarities of each kind of steel have been taken into account. In the Bessemer process the original phosphorus and sulphur in the stock will remain in the steel and more sulphur will be taken up in the cupola. In the Acid Open Hearth process the original phosphorus and sulphur in the stock will remain in the steel. In the Basic Open Hearth process the original phosphorus and sulphur will be reduced. It is not intended that any comparison should be made between the corresponding qualities of the different kinds of steel in the tables. In fixing the limits, the possibilities and peculiarities of each process have been considered independently and acted on accordingly. The quality of steel is dependent not only upon its chemical composition, but upon the kind of stock used, the process employed in manufacture, and the skill, knowledge, and experience of those concerned in its making.

Chemical Tests.—In providing for the analysis of steel account has been taken of "segregation." Some of the elements of steel, and most notably phosphorus and sulphur, are not uniformly distributed throughout an ingot, but vary according to natural laws. If a steel is wanted in none of which the phosphorus and sulphur are to exceed a certain amount, then a steel must be specified in which the original amounts of these elements are much lower or provision must be made for discarding about one-half of each ingot.

Irregularities in steel sometimes occur from the imperfect mixing of the re-carbonizing materials and are the result of carelessness or imperfect methods. This imperfect mixing results in "hard spots," due to excessive carbon and manganese at local points and should not be confused with segregation which follows natural laws, while the occurrence of "hard spots" is irregular and without rule.

Number of Chemical Tests.—The number of tests provided, if properly selected, will show the average quality of the steel and give a fair idea of the amount of segregation which has taken place.

Additional Tests.—Additional tests for the protection of the user have been provided for in case the value of the regular tests or their representative character may be questioned, either physically or chemically.

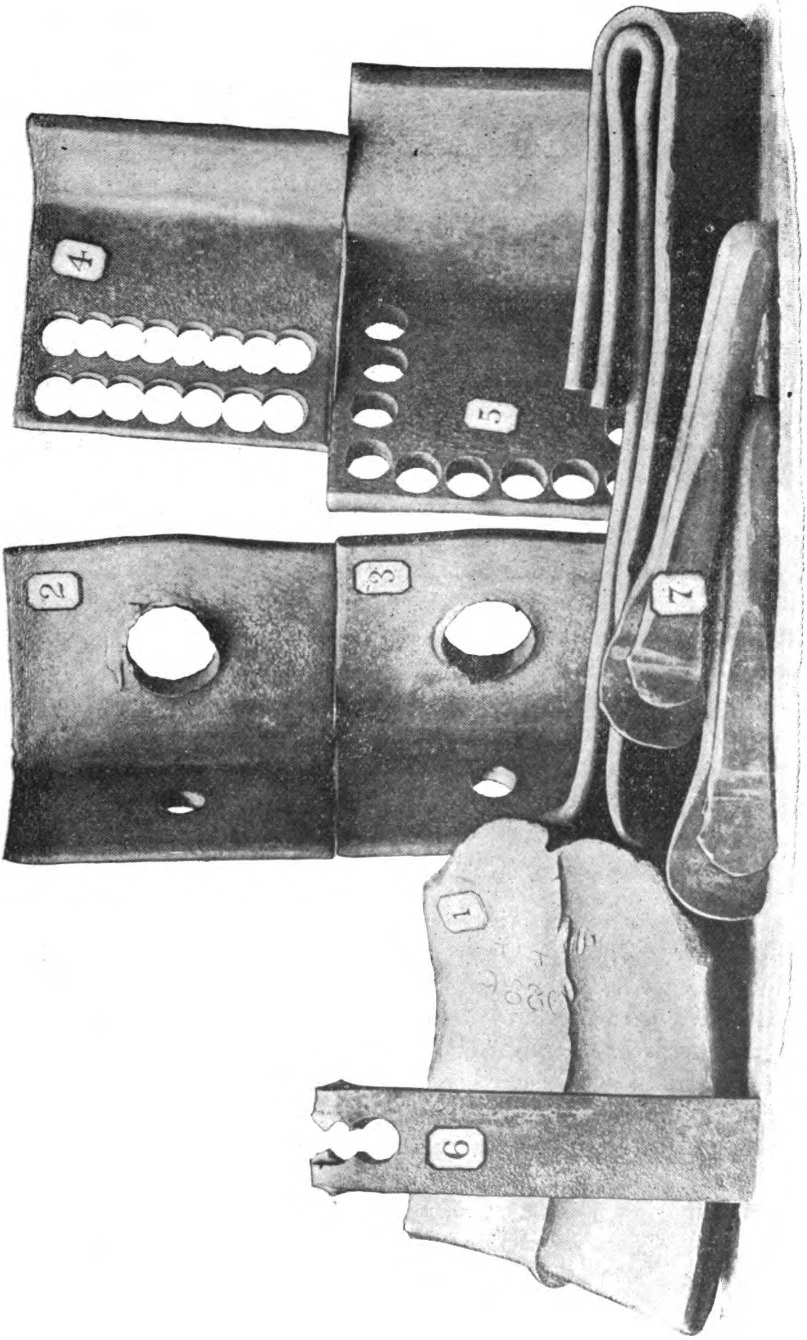
Inspection of Manufacture.—For new or not well-known processes or for mills to which the user may be a stranger, it may become desirable to inspect the entire manufacture in order to form an idea of the value of the product.

Eye-bar Tests.—Under eye-bar tests provision has been made for the natural fall in ultimate strength due to the size of test-piece and softening from annealing. The elongation has been specified in twenty feet as being sufficient to show the quality of the bar in this respect, and to avoid needless complications when bars of small section and unusual length are tested.

The requirements of full-sized tests have been made few and of a general nature, as, in justice to those who make the heads and finish the bars, the grades and quality of the steel used should be definitely determined before any work is done on the bars. Those who finish the bars are responsible for the workmanship on the heads and the heat treatment of the material while in their charge. If the grade and quality are unquestionable to start with, improper workmanship and heat treatment will cause the failure of the test bars under the specified requirements and no question can arise as to the cause of the failure or responsibility therefor.

Frequent complications and rejections arise from the widely varying results of specimen and full-sized tests from the same steel. These are readily understood when it is considered that large amounts of material are frequently accepted on the results of a single specimen test selected from the most favorable location and in no sense representative of the average condition of the material. This specimen test is followed by one or more full-sized test which *may* represent the *worst* condition of the material, and which, if they break in the body, do represent the average condition of the cross-section. Failure of the heads of eye-bars are generally credited to bad workmanship, but they are quite as likely to be due to inferior steel at the place of rupture.

The discrepancies between specimens and full sized eye-bar tests in ultimate strength are sometimes remedied by annealing the specimen tests. This is not necessary when a sufficient range of variation has been allowed in the first place and is objectionable for the following reasons: Annealing a specimen test not only lowers the ultimate strength, but increases the elongation and reduction and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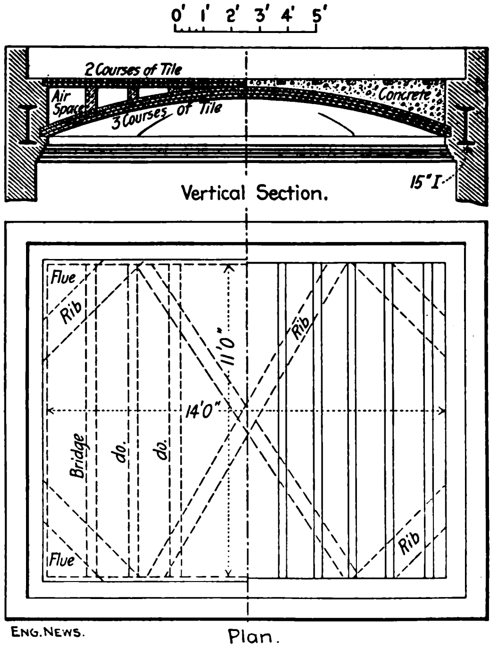
improves the appearance of the fracture; consequently steel which might be objectionable in its ordinary condition may be accepted after annealing, and the question is always open as to whether the full-sized bars have been annealed under the same conditions and with the same care and attention as the annealed specimens. If we know that our steel was originally acceptable we may be certain that if properly annealed it is still good. If we do not know what its original condition was we have no positive assurance that the full-sized bars are not inferior to the annealed specimen tests which we may have made.

Where a sufficient range in ultimate strength has been provided and steel is unquestionable as to grade and quality, unannealed specimen tests will prove satisfactory and there will be few rejections of full-sized test bars.

Conclusion.—In these specifications the existing conditions of manufacture have been taken into account, and they have been so framed that the user may readily provide for any grade or quality of steel desired. Difficult, unusual, and excessive requirements have been omitted, as they are of little practical value to the user, are difficult to enforce, and are often the cause of annoying and serious delays to the manufacturer. Some of the supposed severe tests that are required of steel are in reality easy, and such specified requirements would be readily passed by steel of very common quality.

TEST OF THE GUASTAVINO FIREPROOF FLOOR.

A TEST was made on April 2d by the Building Department of New York city, at the testing grounds, Sixty-eighth Street and Avenue A, of the system of fireproof floor construction of Mr. R. Guastavino, 11 East Fifty-ninth Street. The test was made in the same manner as the other tests which have been described in our columns during the past six months. The floor was built so as to form the roof of a brick building, 11 × 14 feet, inside dimensions, and about 12 feet high. An illustrated description of this system of flooring, as used in the Boston Public Library building and in the Arion Club building in New York city, was given in our issue of November 9th, 1889. The construction used in the test is shown in the accompanying cut. The principal feature of the construction is an arch formed of three layers of hard, well-burned clay tile, about 1 inch thick, 6 inches wide, and 12 inches long. The lower layer is laid with a quick-setting mortar, composed chiefly of plaster of paris; the other layers are set in a mortar of Portland cement. The thrust of the arch is taken by I-beams, built in the walls, and four shorter I-beams placed diagonally across the four corners. The rise of the arch is 1.1 feet, or 1-10th of the span. The flat floor above the arch was built in two forms, as shown in the cut, one on each side of the centre line. On one side it was made of two layers of tile, set in cement, with supporting ribs, enclosing air spaces, and on the other the whole space up to the floor level was filled with concrete.



Previous to the test the floor was loaded with pig-iron to 150 pounds per square foot. With this load the floor showed no deflection. During the test a fire of cordwood was maintained for five hours on the wrought-iron grate near the ground floor of the building, and a second grate, one foot below the first, caught the hot embers by which the air admitted to the fire was heated. The temperature of the room below the arch was measured by a Uehling & Steinbart pyrometer. At the end of the first hour after starting the fire the temperature had reached 1,975° F., and thereafter, until the end of the test, it ranged from 2,000° to 2,500°. The fire, on the average, was hotter than any of the previous tests by the department, which was probably due to the warm, dry weather which prevailed and the dry condition of the firewood During the fire, instead of any deflection being shown, the floor rose ¾ inch by measurement at the centre, the rise being caused, no doubt, by the expansion of the materials of the arch. At the end of five hours the fire was quenched by a powerful stream of water from a fire engine, 60 pounds gauge pressure being maintained at the engine. The stream was directed against the under side of the arch. The force of the stream and the sudden cooling detached some of the tiles of the lower layer, but the remainder of the arch was uninjured, and sustained the load. The deflection, measured after the cooling by water, was 0.22 inch, but when the load was removed the arch rose 0.05 inch, so that the final deflection was 0.17 inch. The next day the arch was loaded again with a burden of 600 pounds per square foot (over 50 tons in all), the loading taking about six hours. During the loading the floor gradually deflected to a total of 0.37 inch, at which it remained. The ceiling where the tiles were detached is to be repaired, and another fire and water test is to be made of the same arch in about ten days.

CEMENT IN SEA-WATER.

The Behavior of Hydraulic Cements in Sea-Water.

By Dr. William Michaelis.

If the hydrates of silica, peroxide of iron, and alumina be exposed to the action of a solution of lime (lime water) which is kept constantly at the point of saturation, the following lime compounds are formed as representing the highest degrees of combination:

$$2SiO_2,\ 3CaO + xH_2O$$
$$2Fe_2O_3,\ 4CaO + yH_2O$$
$$2Al_2O_3,\ 5CaO + zH_2O$$

The values of x, y, and z have not been ascertained with certainty. I estimate these at 6, 7, and 8 respectively; the smallest amount of water corresponds to 1 equivalent of CaO to 1 equivalent of H_2O.

As long as no certain proof is brought forward that other compounds are formed in the process of hydraulic hardening, as a result of the action of the water upon highly limed hydraulic cements, it may be assumed that the above-mentioned combinations take place, and that the superfluous lime separates out as hydrate of lime, as is evidently the case with Portland cement, which, in its hardened condition, is found to be completely permeated with crystals of calcium hydrate.

H. Le Chatelier is known to accept a crystallizing compound as the stable hydro-silicate of calcium—$2CaOSiO_2+5H_2O$; similarly a hydrated aluminate—Al_2O_3, $3CaO+12H_2O$. Whether, in the process of hydraulic hardening, hydro-silicate of lime is crystallized, or whether, as I believe, it cannot crystallize on account of its absolute insolubility,* but is a colloid body, does not affect the following considerations.

It is known that the compound Al_2O_3, 3 CaO, on taking up water, "blows" violently; therefore I do not consider this compound as the predominant one in Portland cement of normal composition. On the most unstable hydro-ferrate of lime, which is entirely decomposable by water, Le Chatelier says nothing further. Moreover, no other combination has been established than the one above mentioned.

In agreement with E. Candlot I have discovered the following crystallizing calcic alumino-sulphate compound: $2\ (Al_2O_3,\ 3\ CaO) + 5\ (CaOSO_3) + 80\ H_2O$ (dried over sulphuric acid). E. Candlot gives 120 H_3O for the air-dried crystals, but, after drying over sulphuric acid, I have also observed † the combination $Al_2O_3,\ 3\ CaO + 3\ CaOSO_3 + 30\ H_2O$.

For the following considerations we shall take into account only this second compound which crystallizes with 30 equivalents of water—that is, with less water, which must indeed be the case.

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[*] The insolubility must thus be understood, that when calcium oxide is present silicic acid is quite insoluble in water; the hydro-silicate of lime is indeed decomposed by the water, but is never dissolved as such; only the lime is dissolved.

[†] The compound dried by air:

$$2\ Al_2O_3,\ 3\ CaO + 5\ CaO\ SO_3 + 80\ H_2O$$

gave, when dried over sulphuric acid, 22 H_2O

[therefore, perhaps $2\ (Al_2O_3,\ 3\ CaO + 6\ H_2O) + 5\ (CaO,\ SO_3 + 2\ H_2O)$]

dried at 100° 16 H_2O

ignited to deepest red heat it was entirely free from water. The anhydrous double salt dissolves in 2,214 parts by weight of water at 18°.

Every part by weight of alumina, which forms in the first place a hydro-aluminate of lime in hydraulic mortars, has the power of forming about 12 parts by weight of this double salt.

The hydro-ferrate of lime compound behaves similarly; I have established its composition as Fe_2O_3, 3 CaO + 2 CaO, $SO_3 + x H_2O$, but I have not been able to obtain it in a crystalline form. As this is not yet beyond doubt, it will not be taken into account at all in the following considerations. Only this much may be assumed, that it acts in the same way as the double alumina compound:

Part by Weight.		Parts by Weight.	
1 of Al_2O_3,	forms	3.062	$2 Al_2O_3, 5 CaO + 8 H_2O$.
1 " Al_2O_3,	"	3.7	$Al_2O_3, 3 CaO + 6 H_2O$.
1 " Al_2O_3,	"	4.735	$Al_2O_3, 3 CaO + 12 H_2O$.
1 " Al_2O_3,	"	11.856	Alumino-sulphate of lime.
1 " $Al_2O_3, 3 CaO + 6 H_2O$,	"	3.2175	Alumino-sulphate of lime.
	or	4.4636	E. Candlot's double salt, with 120 H_2O.
1 " CaO, SO_3,	forms nearly	3	Alumino-sulphate of lime.
1 " CaO, H_2O,	"	2.3243	$CaO, SO_3 + 2 H_2O$.

The real Roman cements with a hydraulicity ratio of 1 part by weight of silicate [silicic acid, alumina, ferric oxide (manganese oxide)] to 1.1 to 1.2 parts by weight of calcic oxide are, from a chemical standpoint, the best water cements, as in the hardening process they form the most stable compounds without any portion remaining uncombined.

As an example, a Roman cement of the following composition:

	Per Cent.		
Silicic acid,	= 24.00	or, in equivalents,	0.400
Alumina,	= 10.28	" "	0.200
Ferric oxide,	= 4.80	" "	0.030
Calcium oxide,	= 49.00	" "	0.875
Sulphuric acid,	= 3.20	" "	0.040
Magnesia, Alkalies,	= 5.00		
Insoluble matter,	= 3.72		
	100.00		

requires, if one takes the compounds richest in lime mentioned at the beginning:

$$2 SiO_2, 3 CaO; \ 2 Fe_2O_3, 4 CaO; \ 2 Al_2O_3, 5 CaO$$

$$0.4 \times \frac{3}{2} + 0.2 \times \frac{5}{2} + 0.03 \times 2 + 0.04 = 1.2 \text{ equivalents.}$$

or 67.2 parts by weight of calcium oxide. As only 0.875 equivalents of calcium oxide are present, compounds so rich in lime cannot be formed, but there will be produced calcic compounds poorer in lime, and therefore more stable: SiO_2, CaO; 2 Al_2O_3, 3 CaO; 2 Fe_2O_3, 3 CaO, for which only 0.785 equivalents, or 43.96 parts by weight of CaO are requisite; the remaining 5.04 parts by weight of calcium oxide are then used for the formation of compounds richer in lime. No free, uncombined lime remains over in the hardened cement.

A water cement thus composed fulfills its object in the most perfect manner. Independent of the double compound of calcic alumino-sulphate—Al_2O_3, 3 CaO + 3 CaO, SO_3 + 30 H_2O—this Roman cement would give, on hardening, only the following stable compounds:

Hydro-silicate of lime with 1 to 1.5 CaO to 1 SiO_2
Hydro-aluminate of lime with 1 to 3 CaO to 2 Al_2O_3
Hydro-ferrate of lime with 1 to 3 CaO to 2 Fe_2O_3.

Gypsum, hydrates of magnesia, and the alkalies, only the last two of which remain uncombined, but which produce with sulphuric acid salts which are not injurious, but are easily soluble. As the Roman cements can only be produced with a red heat—indeed, only with a moderate red heat—which does not effect their condensation, they form, from a physical standpoint, only loose cements, which accordingly contain the compounds formed on the absorption of water in a very expanded condition, and this is the reason why the mortars made with them shrink very considerably when dried in the air, by the loss of the loosely combined water. All the water which these hydrates contain beyond the amount which corresponds with that in lime hydrate must, however, be regarded, down to the smallest quantity, as loosely combined or "slaking" water.

The hydraulic limes, of which the lime from Teil (Southern France, Department d'Ardêche) may be regarded as the best representative, are near the Roman cements in their physical aspect; they are for the most part still looser, at least, the so-called light hydraulic limes.

If one considers the lime from Teil, which in a freshly ignited condition contains:

	Per Cent.			
Silicic acid, ...	= 22.80	or, in equivalents,		0.380
Alumina, ...	= 2.57	"	"	0.025
Iron oxide, ...	= 0.88	"	"	0.0055

Sulphuric acid, ...	= 0.64	or, in equivalents,	0.008
Calcium oxide, ...	= 68.60	" "	1.225
Magnesia, ...	= 1.60		

and if, on hardening, one takes the compounds richest in lime, these use up

$$0.38 \times \frac{3}{2} + 0.025 \times \frac{5}{2} + 0.0055 \times 2 + 0.008 = 0.6515$$

equivalents, or 36.48 parts by weight of calcium oxide. An uncombined remnant of 32.12 parts by weight CaO, and 1.6 parts by weight of magnesia is therefore left.

Portland cement, which, from a physical standpoint, is very superior to the Roman cements and hydraulic limes, as it is in a high degree condensed by the semi-fusion which it undergoes at white heat, must, when it swells in like manner in the hardening process, become, in a far greater degree, condensed, because the much denser particles lie nearer one another, thus offering, in the same space, a considerably greater amount of expanding material. The average proportion in mass of Portland cement to Roman cement in the same space, is about 5 : 3, and to hydraulic lime about 5 : 2.5 to 2; the semi-fused Portland cement has thus a much greater weight, bulk for bulk, and the mortar attains, accordingly, a much greater strength and closeness of grain, or rather density; for the Roman cements and hydraulic limes also exhibit a completely close structure.

The Portland cements, on the other hand, are less valuable from a chemical point of view, because like the Teil lime, a very considerable quantity of calcium oxide, striving for combinations is produced in the process of hydraulic hardening. If, for example, two Portland cements are considered, one of which (*a*) contains the minimum, the other (*b*), the maximum amount of lime, viz., with one part by weight of silicate to 1.7 of calcium oxide, and with one part by weight of silicate to 2.32 of calcium oxide, and of which (*a*) contains:

	Per Cent.		
Silicic acid, ...	= 22.50	or, in equivalents,	0.3750
Alumina, ...	= 8.90	" "	0.0875
Irox oxide, ...	= 4.00	" "	0.0250
Sulphuric acid, ...	= 1.00	" "	0.0125
Calcium oxide, ...	= 61.04	" "	1.0900
Magnesia, Alkalies, etc., }	= 2.47		
	100.00		

it is found that the hydraulic compounds richest in lime require— 0.84375 equivalents, or 47.25 of calcium oxide; thus at least 13.79 parts by weight of calcium oxide remains uncombined, besides magnesia and alkalies. In the cement (*b*), which is richer in lime, with a composition of:

	Per Cent.		
Silicic acid,	= 20.778	or, in equivalents,	0.3463
Alumina,	= 5.819	" "	0.0566
Iron oxide,	= 2.720	" "	0.0170
Sulphuric acid,	= 0.520	" "	0.0065
Calcium oxide,	= 68.379	" "	1.2210
Magnesia, Alkalies, etc.,	= 1.784		

a remainder of 1.221—0.70145 equivalents, or 29.1 parts by weight of calcium oxide is found, if we consider the compounds, richest in lime, as being really formed in the process of hardening.

In a Portland cement, of a medium composition, with 1 part by weight of silicate to 2 parts by weight of calcium oxide, about 25 per cent. of lime, or about 33 per cent. of calcium hydrate, separates out. This calcium hydrate is easily recognized, in a crystallized form, in every Portland cement, if it has not had the opportunity of passing into calcium carbonate.

It is easily understood that a body in which so considerable a quantity of quicklime (a substance of exceptionally strong affinity) becomes liberated, cannot be, in the chemical sense, a stable compound. The free lime must work and react until, in one way or other, it forms a saturated compound. This occurs first from the surface downwards by the absorption of carbonic acid, when the cement is exposed to the air or to water containing carbonic acid; in sea-water it is principally the soluble sulphuric acid compounds which react on the lime. First, the perfectly free lime changes, according to circumstances, into calcium carbonate or sulphate; next, that which is present in the form of the extremely unstable ferric oxide compound; thereupon follows the attack on the calcium aluminate, and, lastly, on the silicate.

Even the simple formation of calcium sulphate, with two equivalents of water, causes a considerable increase of volume, and is sufficient for the destruction of the cohesion produced by the absorption of water. But with this gypsum is connected the formation of calcic alumino-sulphate (see "The Cement Bacillus," *Engineering*, July 1st, 1892), whose formation produces a formidable increase of volume, and, as a result, the total destruction of the cohesion, because this double compound crystallizes with at least 30, probably with 60, equivalents of water; it splits up thus grain by grain the hardest mortar with irresistible force to a completely disorganized mud, in which only the parts protected by the formation of calcium carbonate can maintain a certain degree of coherence.

If the Roman cements, hydraulic limes, and Portland cements be examined for this formation of calcium sulphate, and then of calcium alumino-sulphate, and if one accepts the above-selected types, it appears that in Roman cement all the lime is combined, and has no inclination to react with magnesium sulphate. The 5.44 parts by weight of calcium sulphate present in the mortar forms, however, with the existing calcium aluminate, at least 16 parts by weight of the double salt—that is, with an accession of about 11 parts by weight of solid matter; this quantity, however, most probably finds enough room in the pores of the mass. For, according to my observations, as well as the experience of others, good Roman cements withstand the action of sea-water excellently.

In the Teil lime, as a general rule, a large part of the liberated lime is changed into calcium carbonate by the longer period of hardening in the air before being used in sea-water, and the formation of gypsum is thus prevented. Assuming that no appreciable formation of calcium carbonate takes place, about 30 parts by weight of calcicum oxide would be available for the formation of gypsum, and thus 92.144 parts by weight of gypsum would be produced from the 39.643 parts by weight of calcium hydrate, which would alone destroy the cement; but moreover, from the existing 5.97 parts by weight of calcium aluminate with a part of this gypsum, about 30 parts by weight of the double compound are formed; an increase in solid matter of about 60 parts by weight results thereby (namely, 30 parts by weight of double salt + 92 parts by weight of gypsum minus the existing 39.6 parts by weight of calcium hydrate + 9.25 of calcium hydro-aluminate + 13 parts by weight of gypsum, used in the formation of the double salt).

Here then the formation of the gypsum plays the principal part, this alone gives an increase of mass of 52.5 parts by weight; on the other hand, the formation of the double salt is of less importance, because the hydraulic limes generally contain little alumina, and consist mainly of lime and silica. Doubtless, the double salt has a much stronger crystallizing energy, and also a greater "blowing" power.

In a Portland cement containing a medium quantity of lime, say, with 64 per cent. of calcium oxide, 7.2 per cent. of alumina, and 0.8 per cent. of sulphuric acids about 25 per cent. of CaO, or about 33 parts by weight of CaH_2O_2 respectively, as we have seen, separate out, which by reaction with magnesium sulphate are converted into 74.5 parts by weight of gypsum, thus causing an increase in mass of 41.5 parts by weight. The existing 7.2 per cent. of alumina had formed 26.64 parts by weight of calcium hydro-aluminate, and now, in combination with the gypsum which is present, changes into at least 85 parts by weight of double salt. The entire increase in mass amounts here to 74.5 gypsum + 85 double salt minus the existing 33 CaH_2O_2 + 26.64 calcium hydro-aluminate + 36 out of the existing gypsum = in round numbers 64 parts by weight. This enormous increase of mass on about 125 parts by weight of hydraulically hardened cement must inevitably cause its total destruction, unless specially favorable circumstances check or weaken the action of the soluble sulphates of the sea-water. Such circumstances may be partly of a chemical, partly of a physical nature.

Carbonate of lime cannot be decomposed by sulphates at a normal temperature; the utmost possible change of the superfluous calcium hydrate into calcium carbonate forms, therefore, the best means of protection, and the explanation of the fact that, for example, Teil lime has proved more durable than Portland cement, which is, as a rule, exposed immediately to the action of sea-water, must be sought in the circumstance that the hydraulic limes when used for marine constructions, on account of their somewhat slow initial hardening, are allowed to harden in the air, thus, at the same time, absorbing carbonic acid abundantly before they are sunk, in other words, before they are exposed to the action of the sea-water.

It has therefore been well understood, and on quite sufficient grounds—that is, as I had the opportunity of observing specially at Boulogne-sur-Mer—the blocks made with Portland cement concrete have been allowed to harden for a long time in the air, and thus become enveloped with a protective covering, in which the free lime is enabled to form calcium carbonate, before the blocks were sunk under the sea. If, however, the sea-water is able later to enter into the interior of the block, into which the carbonic acid has not penetrated (indeed, only a relatively very inconsiderable layer can have been entirely saturated with carbonic acid within a moderate period), reaction and destruction set in, and the outer carbonated shell is burst and upheaved with irresistible force from the rapidly decomposing interior.

Calcium silicate resists tolerably well a transformation into calcium carbonate, at least a total transformation. The carbonate acid acts here just like the water; the lime (exceeding one equivalent) is much more easily soluble in water, and, also, is more easily converted into calcium carbonate; the poorer the combination is in lime, the more stable also it is as against the attack of the carbonic acid. It is very difficult entirely to convert the lime into carbonate, even in small pieces of mortar of 50 to 100 cubic centimetres in a pure damp carbonic acid atmosphere.

Calcium aluminate is more easily decomposed, and the compound of lime and ferric oxide is entirely decomposed by carbonic acid.

The following experiment was made on the influence of carbonic acid and the manner in which it acts, more especially on the strength of Portland cement mortar, and the power of resistance of the latter to sea-water.

From 1 part by weight of Portland cement from Stettin (Stern brand) and 3 parts by weight of Berlin standard sand, also from 1 part by weight of this cement and 5 parts by weight of standard sand, 10 briquettes respectively for testing tensile strength were prepared with perfectly smooth and parallel surfaces, according to the German standard process. These were left to harden for the first 24 hours, carefully protected under a bell jar from carbonic acid and in a damp atmosphere, and afterward for 56 days in hermetically closed flasks in boiled distilled water. Half of each set of briquettes were then treated with damp carbonic acid under a bell jar for five weeks; these were then placed with the others in the flasks in order to harden under water for four weeks more. In the testing which followed as to tensile strength and resistance to compression (the broken briquettes were put together again, and while held together with an elastic band were submitted to the compression test), the specimens were thus 120 days old. The result of the testing was as follows:

Cement Mortar 1 : 3.				Cement Mortar 1 : 5.			
(*a*) Protected from CO_2.		(*b*) Treated with CO_2.		(*c*) Protected from CO_2.		(*d*) Treated with CO_2.	
Tensile Strength.	Compression Strength.	Tensile Strength.	Compression Strength.	Tensile Strength.	Compression Strength.	Tensile Strength.	Compression Strength.
378	4,300	392	4,800	192	1,642	221	1,985
364	4,614	428	5,200	192	1,642	285	2,142
400	4,714	407	5,342	200	1,371	235	1,857
400	5,100	414	4,600	207	1,500	221	1,971
371	3,385	392	4,228	207	1,885	235	1,900
Average, 282	4,422	406	4,834	199	1,608	239	1,971

The numbers indicate pounds per square inch.

. How much of the lime contained in the cement has been converted into carbonate of calcium in the cases of *b* and *d*? How great was the amount of water contained in the cement protected from carbonic acid and in the cement treated with carbonic acid after drying over sulphuric acid?

The mortars furnished: Per Cent.
1 : 3 *a*. Carbonic acid, ... = 0.565
Chemically combined water, ... = 3.046
1 : 3 *b*. Carbonic acid, ... = 1.506
Chemically combined water, ... = 3.150
1 : 5 *c*. Carbonic acid, ... = 0.483
Chemically combined water, ... = 2.336
1 : 5 *d*. Carbonic acid, ... = 1.954
Chemically combined water, ... = 1.896

In the mortar 1 : 3 there was 14.383 per cent. of calcium oxide, in the mortar 1 : 5, 10.000 per cent of calcium oxide; while in *b* only 13.3 per cent., and in *d* only 24.86 per cent. of the entire amount of lime was converted into carbonate. It is seen that the absorption of carbonic acid, even with such small bodies as those used for the (German) standard method of testing tensile strength (about 70 cubic centimetres by 22 millimetres in height) proceeds but very slowly in pure (damp) carbonic acid; that, in other words, it is very imperfect, and, moreover, requires a very lengthy treatment in order to decompose the calcium silicate and calcium aluminate; that, therefore, even a very long exposure of concrete blocks to the air will only bring about, in every case, a superficial carbonation. This process offers no sufficient means for the protection against the destroying influence of the sea-water.

Only in a coarsely-pulverized condition, and for a long time exposed to the influence of carbonic acid, is the entire quantity of lime finally converted into carbonate; this proves, as already above indicated, that the action of the carbonic acid may be compared to that of fresh water; the poorer they are in calcium, the more capable of resistance do the hydro-silicates and aluminates become.

Some halves of the broken briquettes were then placed in sea-water and in a 2 per cent. solution of magnesium sulphate; those which had been protected against the absorption of carbonic acid were rapidly decomposed; but those also which had been treated with carbonic acid were severely attacked after only seven months, and the more porous mortars 1 : 5 were visibly more strongly attacked, although they had absorbed more carbonic acid.

The hydraulic mortars exposed to the action of sea-water should therefore consist of the most stable compounds of calcium hydrate with hydrates of silicic acid, alumina, and ferric oxide:

$$2\ SiO_2,\ \sum_{1}^{3} CaD \text{ and } 2\ Al_2O_3 \sum_{1}^{3} CaO.$$

In fresh water the circumstances are much more favorable; here the free lime can only either be dissolved or converted into carbonate. The more lime is washed away by the water, with the more difficulty will the remaining lime, combined with silicic acid or alumina, become dissolved, as Le Chatelier has already established, and as my experiments with small, perfectly hardened pieces of pure Portland cement have shown me. In this way the mortar can indeed become more porous, but the complete solution of the entire amount of lime can never occur. In very small quantities Portland cement, if it has been protected against the absorption of carbonic acid, can be perfectly freed of its lime by digestion with boiled distilled water, as I have already long since demonstrated, and that in such a way that only the hydrates of silica, alumina, and ferric oxide remain; but in pieces of only a few cubic centimetres in size, a treatment with very large quantities of water, continued for years, is necessary to produce their complete decomposition.

Thus, in fresh water, exactly the opposite process occurs, the lime partly leaves the mortar, rendering it somewhat more porous; but in a perfectly made cement a state of tension never occurs, nor, as a consequence of this, a destruction by "blowing." When Portland cement, with from 64 to 66 per cent. CaO—or, if the most perfectly combined and burnt cement, with up to nearly 70 per cent. CaO (fused Portland cement)—hardens with water, the combining force in the formation of the hydrates is greater than the extending force of expansion, provided the lime separates out equally through the whole mass. In this case the lime increases in volume just as little as does the most finely pulverized quicklime when it is mixed first in the dry state with sand to a mortar, and then gauged with water. The increase of volume which then takes place appears to occur in the porous interstices, and an increase in density of the mass ensues, as is also distinctly shown by its appearance. The matter is different when imperfect physical mixtures are burnt; then there are found in the semi-fused cement uncombined lime (in the interior of the larger lime granules), and silicates, aluminates, and ferrates too rich in lime, of which it is well known that those with a composition of three and more than three equivalents of CaO to one equivalent of SiO_2, Al_2O_3, and Fe_2O_3, show an increase of volume on the addition of water similar to that occurring in free lime. However, I have obtained, in the case of fused Portland cement, proof that there is Portland cement which perfectly constant in volume—*i. e.*, free from any signs of "blowing," with a composition of 1 part by weight of silicate [silicic acid, alumina, ferric oxide (manganese)] to 2.4 parts by weight of calcium oxide, or, according to the French method of reckoning, with a hydraulicity factor of 0.416.

It is very plain that a close structure, such as insures impermeability to water, is a very essential auxiliary.

The magnesia which has been so long calumniated, and which separates out as the result of the reaction of the sea-water on hydraulic cements, and to which the destruction of the latter has been falsely ascribed, is, on the contrary, a means of protection; for, when the molecules of the magnesium sulphate make the exchange with the calcium hydrate, the insoluble hydrate of magnesia separates out, and helps, by a closing of the pores, to increase the density, and therefore also the imperviousness to water.

The incorrect way of speaking of the "harmful influence of the magnesic salts" should no longer be employed, for correctly expressed, it is only a question of the injurious action of the sulphuric acid of the soluble sulphates. Magnesium sulphate is indeed the sulphate which is mainly active in sea-water; but calcium sulphate, the sulphates of the alkalies, in short, every sulphate soluble in water has exactly the same destructive action, but does not possess an equal degree of energy.

Other mechanical means of protection are incrustations of plants and animals, or a coating of mud, which stop up the surface pores and hinder the continuous action of the sea-water.

My researches have proved that, independant of physical qualities, those hydraulic mortars which are richest in lime are the least able to withstand the action of sea-water, and that nothing can be more mistaken than to add lime to such mortars when they are being prepared. The fact that Portland cement mortars and hydraulic lime mortars are much less durable than Roman cement mortars, though the former are much richer in calcium aluminate, is a clear proof that the free lime, or that which becomes free, is the principal cause of the destruction by sea-water. The more lime Portland cement contains the more calcium hydrate remains free and in need of combination, and the greater is the increase in bulk brought about by the formation of gypsum; hence also is the fact observed that the stronger Portland cements manufactured at present prove less well adapted for marine constructions than those made formerly which were poorer in lime. The cement given above as an example, which contained the greatest amount of lime used in practice, although it can form less of the double salt, would still suffer a greater increase in mass, viz., 70 parts by weight on every 125 parts of the fully hardened cement, if the entire amount of lime which is separated can be converted into calcium sulphate, and the entire amount of calcium hydro-aluminate into the double compound—calcium alumino-sulphate with only 30 equivalents of water.

An hydraulic cement containing free hydrate of lime is just as unstable from a physical as from a chemical standpoint. Even with only a hygroscopic absorption of water swellings of the substance occur, and, therefore, strong pressure strains are produced. Molecular changes begin afresh with every addition of water. Next the alkalies are liberated; these again energetically attract water and carbonic acid to pass on this last at once to the calcium hydrate. It is well known that quicklime can only absorb carbonic acid when free water is present; dry carbonic acid has no effect on dry calcium hydrate.

On the other hand, every time the material becomes perfectly dry the converse takes place; tensional strains are set up leading to the formation of shrinkage fissures, the hydrates losing water and contracting sensibly. The lime does not, indeed, form one hydrate only; we must assume the existence of hydrates with from five to eight equivalents of water, although this is difficult to prove with certainty. Without doubt there exists a gelatinous calcium hydrate, for which, by separation with absolute alcohol, I have obtained the formula $CaO+5\ H_2O$, and I have probably produced a yet higher hydrate than this.

In this manner cement mortar may be seen working for years, often for tens of years, expanding, rending itself, splitting up, and going to destruction; for every absorption of water produces expansion; every drying, shrinkage; every absorption of carbonic acid, the one or the other, according as the reaction is with a simple hydrate, or with higher hydrates—which processes a body as unelastic as cement mortar is, as a rule, incapable of withstanding for any lengthened period.

The popular saying expresses very appositely the truth with regard to this continuous and prolonged "working" of cement mortar, viz., that "cement never becomes quite dead," a characteristic which is in the highest degree fatal to manufactures of cement wares, and which renders the carrying out of many kinds of work in cement quite impossible.

All these evils must be mitigated if the quicklime remaining (or becoming) free in the hardening process can be laid hold of by offering to it hydraulic silica and alumina, with which it can form the most stable hydrated compounds.

The disadvantages connected with the atmospherie decomposition of the caustic alkalies cannot, however, be guarded against in this way; but these, on account of their small quantity and easy solubility, do not cause such serious inconvenience; no danger to the durability of the mortar arises from these caustic alkalies. When the material is used under water they are simply washed out, and when it is hardened in the air they merely cause a disfigurement, and that only a temporary one; for these results of the "weathering" can be washed away by water; this, however, is not the case with the exudations of lime.

Now it becomes at once apparent that nothing more mistaken could be conceived or recommended than to add slaked lime (kalkbrei) to hydraulic mortars, such as the Portland cement mortars, which already contain an excess of lime; by so doing their destruction is accelerated. My researches have clearly proved that, even in the case of mortars which are exposed to the action of fresh water, this expedient has a result which, although apparently favorable, is in reality prejudicial; for the superfluous lime dissolves all too readily, and by the washing out of the same the mortar becomes progressively more porous, and, therefore, more easily disintegrated. Even in two or three years a considerable decrease in strength occurs in such a cement-and-lime or bastard mortar. Carbonic acid may, of course, often react favorably in such cases. I have long ago established the fact that this mode of procedure can be justified only in the case of mortar to be exposed to the air in order to make poor mortars more plastic.

As early as the year 1882 (see No. 33 of the *Deutsche Töpfer und Ziegler Zeitung*) I set forth clearly the position of matters with regard to the excess of lime present in cement, and stated:

"When Portland cement is gauged with water, and, in consequence, hardens, a certain arrangement of the molecules takes place during and as a result of the absorption of the water. In the alkaline water which at once forms in the cement—many cements contain free alkali, and are, in consequence, 'quick-setting'—calcium hydrate separates out in a crystalline form; indeed, in the course of the hardening process, about a third of the whole quantity of lime present in the cement acts thus. The lime thus separated in crystals has very little binding action; it has rather a tendency to destroy the cohesion which the cement mass has already attained. This, however, cannot happen in good cements, because the cohesion is already too strong, and the separation of the lime takes place too gradually.

"After such a consideration of the case, it may be concluded *à priori* that if there are offered to the lime, while it is in process of separating out, Puzzolanas (*i. e.*, substances which in combination with calcium hydrate form cement), the amount of effective cement in the mortar may be increased in such a way that no more caustic lime can be deposited in crystals, but that the entire quantity of calcium hydrate becoming liberated, and which must first go into solution before it can crystallize, is employed in the formation of calcium hydro-silicate (and aluminate)."

The council of the German Cement Makers' Association, in a communication to the Prussian Minister of Public Works in the year 1882, opposed this idea in the following terms: "Normal Portland cements do not require a so-called improving addition; such an addition produces rather a decrease of strength which is nearly proportionate to the amount of the addition;" and, further, "The council is unfortunately of the opinion that the means of coercion which the factories, desiring to furnish for the future an unadulterated article, have at hand, are not sufficient effectively to hold in check these improper practices, and the more so that the desire for gain, which here forms the only motive, does not even disdain to cover itself with the mantle of pretended science, a manœuvre which doubtless has a widespread effect."

In my open letter of the year 1884 to the German Cement Makers' Association, which was directed against this malicious insinuation, I advanced once more, with regard to the hardening in fresh water, the full proof of the correctness of my theoretical propositions.

At the Royal Testing Station for Building Materials in Berlin also no other results could be obtained but such as formed undoubted confirmation of my assertions, and Professor L. von Tetmajer, of the Confederation Testing Institute at Zurich, published in No. 24 of the *Schweizerische Bauzeitung* of the same year his observations on the effect on Portland cement of the admixture of certain substances, which showed an increase of tensile and compression strength, although the density of the substances was much below that of Portland cement (3.1). Thereby the actual improvement of Portland cement by suitable additions was clearly proved to every unbiassed mind.*

From this it was but a step to the conclusion that the improvement by means of additions containing hydraulic silica, of hydraulic cements with an excess of lime must be of the very greatest importance and applicability in the case of mortars which have to be exposed to the action of sea-water, because the study of the behavior of these mortars led me to the conviction that the free lime is the chief cause of the frequent failure and rapid destruction of hydraulic mortars in marine constructions.

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* See "Zum Dogma, etc.," 1884. Further, E. Dietrich *Wochenblatt für Baukunde*, 1885, No. 93, 95; W. Michaëlis, *id.*, 1888, No. 43.

[CONTINUED IN NEXT NUMBER.]

NOTES AND COMMENTS.

NEW BOOKS.

The Materials of Construction.—A treatise for engineers on the strength of engineering materials. By J. B. Johnson, C. E., Professor of Civil Engineering, Washington University, St. Louis, Mo. New York: John Wiley & Sons; London: Chapman & Hall, Limited. Cloth 8 vo, pp. 800, 650 illustrations, 11 plates, and complete index. $6.

Any published work of Professor Johnson will be sought after, for his reputation prior to this work as an engineer thorough in his investigations and originality was established at home and abroad. This work fully sustains his position.

The work is divided into four parts. Part I contains the synopsis of the Principles of Mechanics underlying the laws of the Strength of Materials:

Chapter I. General Nature and Deformation of Stress.
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Hydraulic Cement—Its Properties, Testing and Use. By Frederick P. Spalding, Assistant Professor Civil Engineering at Cornell University; member of American Society of Civil Engineers. Prof. Spalding has compiled an excellent treatise on this highly important subject. There are 265 pages, embodying the author's observation of the behavior of cement in use and in the laboratory. Testing methods are clearly treated, and machines illustrated. The recent recommendations and methods of testing in Europe are also fully given. New York: John Wiley & Sons; London: Chapman & Hall, Limited.

Metallurgy of Cast Iron.—A complete exposition of the process involved in its treatment, chemically and physically, from the blast furnace through the foundry to the testing machine. By Thomas D. West, practical molder and foundry manager, member of Society of Mechanical Engineers, American and Western Foundrymen's Associations, and honorary member of Foundrymen's Association of Philadelphia. Author of *American Foundry Practice* and *Molder's Text Book.* Cleveland, Ohio: The Cleveland Printing & Publishing Company, Publishers, 1897.

Our readers are well acquainted with the author through the medium of the principal mechanical literature of the country. We are indebted very much to him for the many advances in production and economy in the foundry, and useful practice in testing. The work in question is precisely a true exposition of the treatment of cast iron from blast furnace to testing machine, containing all the essentials for correct treatment in an up to date foundry.

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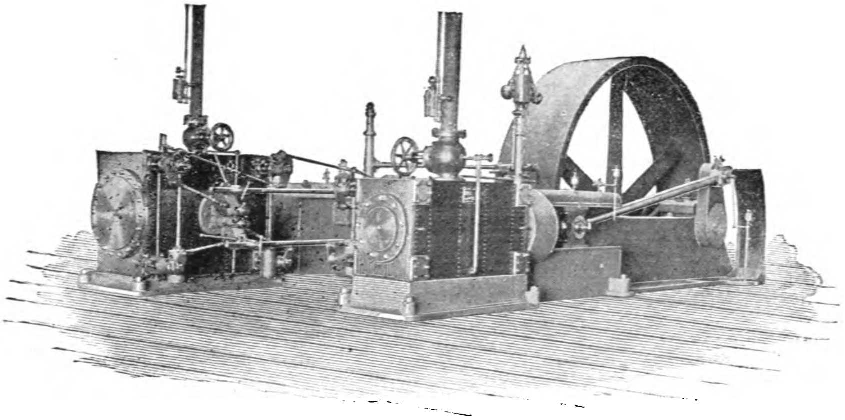

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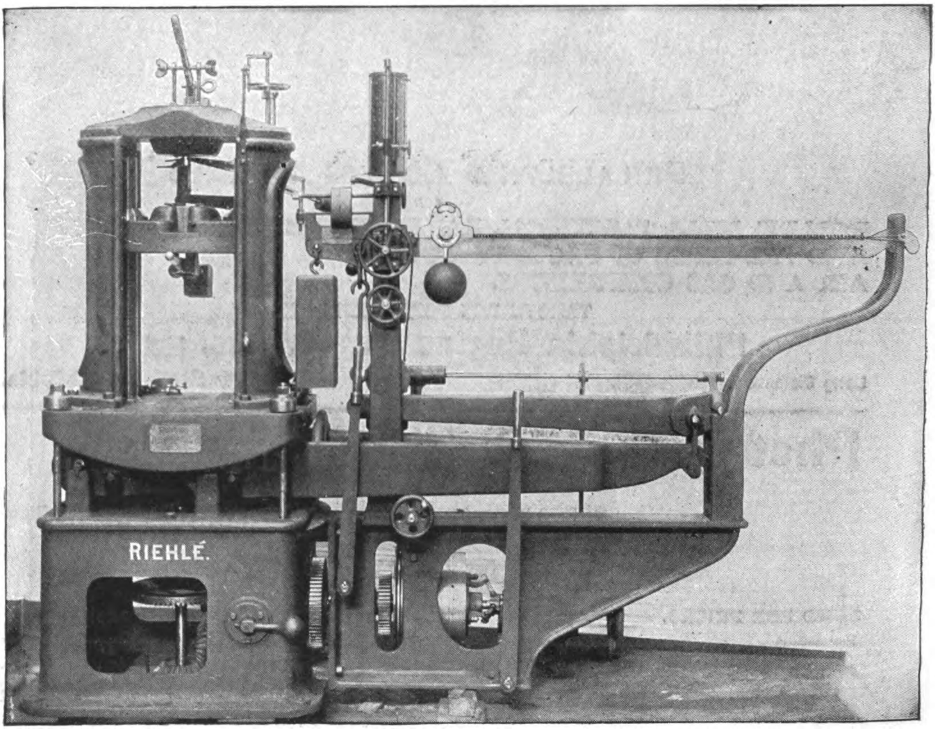

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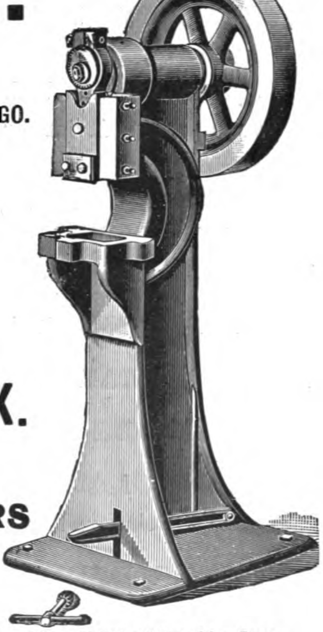

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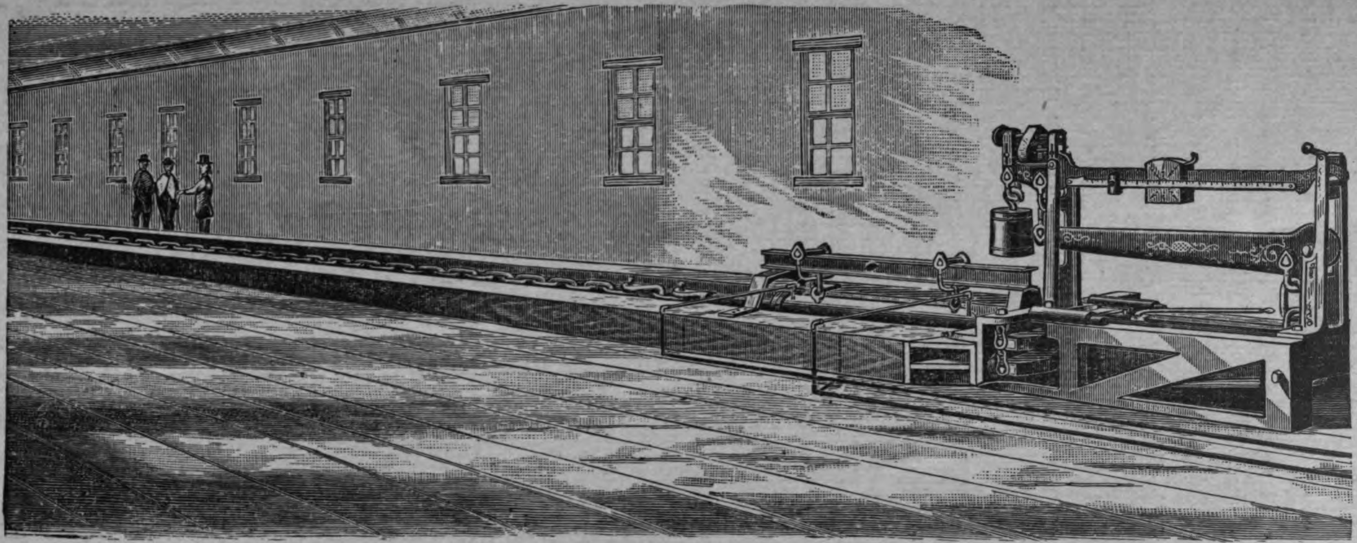

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A résumé of Practical Tests made in the Laboratories of the World.

JOSEPH W. BRAMWELL, EDITOR.

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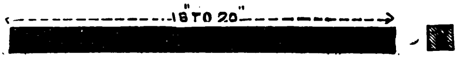

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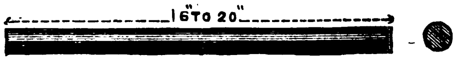

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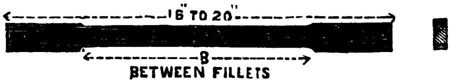

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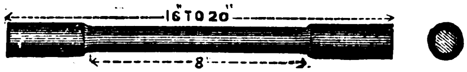

American Society Civil Engineers' standard shape for square or round, turned down in middle.

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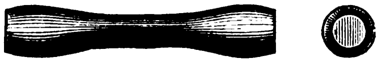

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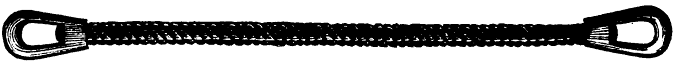

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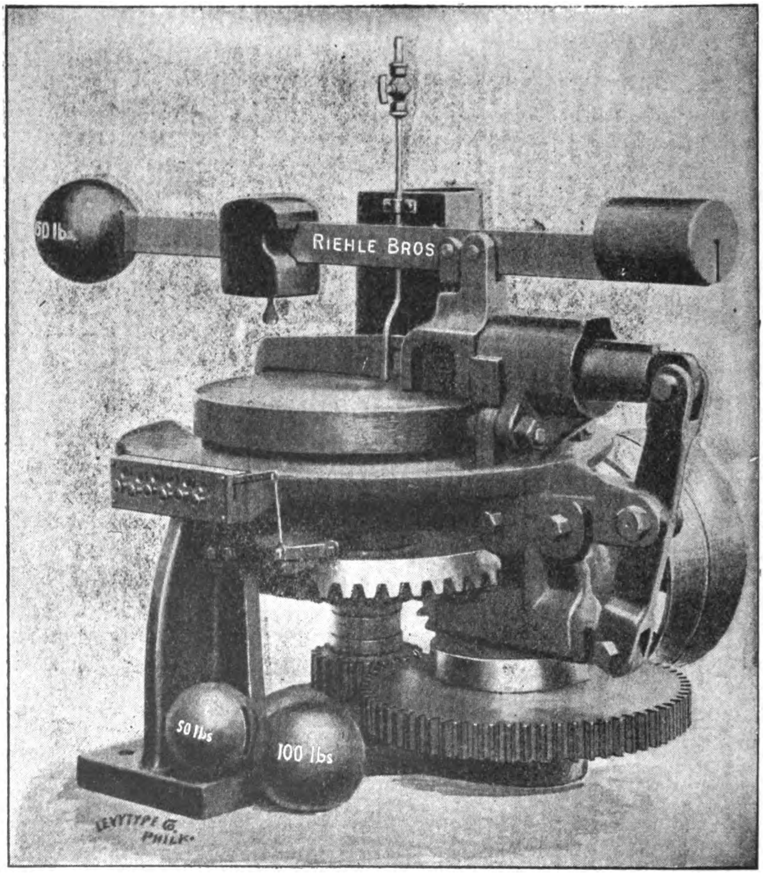

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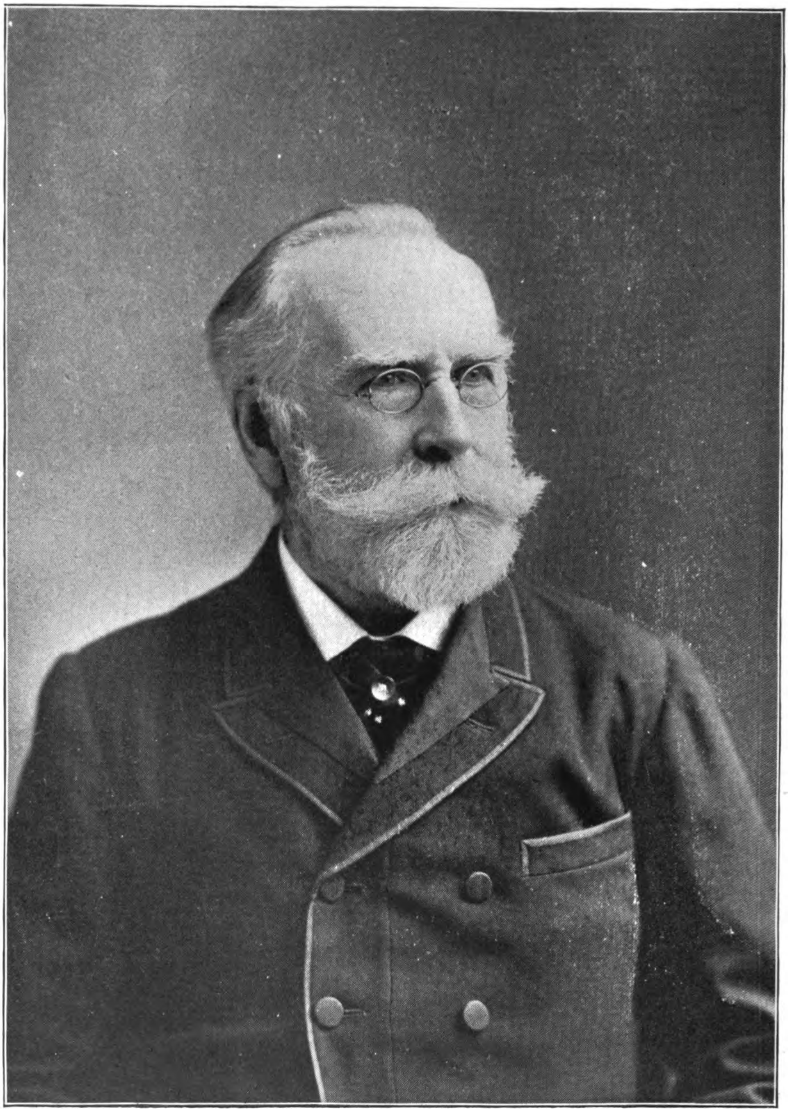

COLEMAN SELLERS.

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Vol. II. **OCTOBER, 1897.** **No. 4.**

DR. COLEMAN SELLERS.

By Frederick A. Riehlé.

DR. COLEMAN SELLERS was born in Philadelphia. His father, Coleman Sellers, was a successful manufacturer, and a man of considerable inventive and mechanical ability. His mother was a daughter of Charles Willson Peale, portrait painter and naturalist.

His preliminary education was received in private schools in this city and afterwards at the academy of Anthony Bolmar, at West Chester. In early boyhood and youth he had opportunities, when not engaged in his studies, to become familiar with the use of tools in the establishments operated by his father and elder brothers, and at the age of nineteen he removed to Cincinnati, Ohio, where he was employed as mechanical draughtsman in the Globe Rolling Mill, and acquiring knowledge of the several processes there carried on, he was very soon put in charge of the works as general superintendent.

In 1850 and 1851 he engaged with an older brother to build three locomotives of the latter's invention for the Panama Railroad. Upon the completion of these engines, late in 1851, he accepted a position with Niles & Company in their locomotive works, and held the position of foreman for about five years.

In 1856 he returned to Philadelphia at the solicitation of his kinsmen, composing the firm of William Sellers & Co., and entered their establishment as chief engineer. In due course he was admitted to partnership and continued therein until 1888, when he retired from active connection with the concern, desiring in the interest of his health at the time to enjoy an extended absence abroad.

While chief engineer with William Sellers & Co., the inventive and mechanical ability possessed by Dr. Sellers assisted materially in giving the establishment the prominence which it has attained, and more than thirty patents bear his name, all being of great utility and value. One of the first of these patents was his coupling device for connecting shafting, which he invented in 1857. This has come into wide use and is important as the essential feature in establishing the modern system of interchangeable parts of shafting. In 1866 he invented and patented an arrangement of feed discs for lathes and other machine tools, which was the first practical solution of the problem of infinite gradation of feeds, and is a device of considerable importance. His other inventions during this period were chiefly confined to new forms of machine tools and modifications of existing ones, and have done much toward advancing the efficiency of machinery and mechanical appliances.

Dr. Sellers also deserves credit for certain useful suggestions outside of his immediate field of labor. The use of absorbent cotton for surgical operations, for example, was first thought of and recommended by him in his contributions to scientific journals as early as 1861. He also proposed the employment of glycerin for the purpose of keeping photographic plates moist, and it is interesting to note in connection with his experiments in the early days of photography, that Dr. Sellers invented and patented in the year 1861 an apparatus in which figures in stereoscopic photographs could be seen as if in motion. This apparatus was christened by Dr. Sellers' uncle, the late Franklin Peale, then one of the chief examiners at the U. S. Patent Office, the name suggested being "Kinomatoscope," and therefore both in name and purpose may be truly accepted as the parent of the so-called Kinetoscope of to-day, that has since been made possible by instantaneous photography and subsequent inprovements in electrical appliances.

In 1889 Dr. Sellers was called upon by capitalists to consider the practicability of the development and utilization of the hydraulic power of Niagara Falls. He was subsequently appointed to represent

America in the International Niagara Commission of five members, with Lord Kelvin as chairman, which in 1890 was established in London to consider various methods of utilizing the power of the Falls, and since that time he has been the active engineering head of the work, both as consulting engineer of the Cataract Construction Company, and president and chief engineer of the Niagara Falls Power Company. The important mechanical design of the large dynamos for the plant was the invention of Dr. Sellers and built under his patents by the Westinghouse Electric & Manufacturing Company. Under his advice and directions important improvements have been made in the hydraulic machinery, and to his mechanical ability, sound judgment, and experience is largely due the success of the entire equipment and its freedom from costly methods so often met with in undertakings of this magnitude.

Besides directing this important work at Niagara Falls, Dr. Sellers is actively engaged in his private practice of Consulting Engineer. Since 1886 he has occupied the chair of Professor of Engineering Practice as a non-resident member of the Faculty of the Stevens Institute of Technology in Hoboken, N. J., and in 1881 he was appointed to the honorary Chair of Professor of Mechanics in the Franklin Institute of the State of Pennsylvania.

He is a member of the American Society of Naval Architects and Marine Engineers; member and Past President of the Franklin Institute of the State of Pennsylvania; member and Past President of the American Society of Mechanical Engineers; member of the American Society of Civil Engineers and of the American Philosophical Society; also of the Institution of Civil Engineers and the Institution of Mechanical Engineers, both of Great Britain, and corresponding member of the Society of Arts of Geneva, Switzerland,

In 1877 the Royal Norwegian Order of St. Olaf was conferred upon him by the King of Sweden in recognition of his valued services in his profession. He was one of the founders and for a time President of the Photographic Society of Philadelphia, and also of the Pennsylvania Museum and School of Industrial Art of Philadelphia. He was a member of the Seybert Commission of the University of Pennsylvania for the investigation of the claims of Spiritualism, being chosen in consequence of his active and clear perception of the laws governing cause and effect and his knowledge of sleight-of-hand, in which art, as a pastime, he has been an expert since boyhood.

THE MICROSTRUCTURE OF STEEL AND THE CURRENT THEORIES OF HARDENING.

By Albert Sauveur.

AT the September meeting of the American Institute of Mining Engineers an important paper was presented by Mr. Albert Sauveur on the microstructure of steel and the current theories of hardening. The discussion of the paper was postponed until the following meeting, which took place last February, in Chicago.

In view of the growing interest of the metallurgical world in the microscopical examination of metals, and because of the fact that a close relation probably exists between the microstructure of the metal, as revealed by the microscope and its physical properties as ascertained in the testing machine, a short *résumé* of the paper and discussion will doubtless be of interest to our readers.

The author first recalls the meaning of the "critical points" of iron and steel.

If a piece of steel containing, say, 0.50 per cent. or more of carbon, be heated to a high temperature and then allowed to cool slowly, the cooling proceeds at first at a uniformly retarded rate until a temperature of about 700° C. is reached, when there is a sudden "retardation" in the fall of the temperature, indicating an evolution of heat, often so considerable as to cause a momentary stop in the cooling, or even an actual rise of the sensible temperature—a "recalescence" of the cooling metal. After this retardation the fall of temperature resumes its normal rate, which is continued until atmospheric temperature is reached. This retardation during the cooling, which indicates that some important change evolving heat is taking place within the metal, is called a "critical point."

In heating, as would be expected, there is a reverse phenomenon, an absorption of heat causing a retardation in the rise of temperature.

While high carbon steels and those of medium hardness have only one critical point, softer steels exhibit, on cooling or heating, two or three critical points.

The purpose of the paper is, first, to describe the changes of microstructure which occur during slow cooling, in steels containing various amounts of carbon, and recently, to examine what bearing, if any, such structural changes as occur at the critical points have upon the current theories of hardening.

The author calls attention to the importance of properly developing the structure of the specimens to be examined through the microscope and describes his methods of etching.

The microscopic constituents of steel are then described at length. All carbon steels, whether quenched or slowly cooled, are made up of one or more of four primary constituents, which have been called respectively: *ferrite*, *cementite*, *pearlyte*, and *Martensite.*

Ferrite is iron free from carbon. It presents three principal modes of occurrence:

1. When present in considerable quantity, as in wrought iron or in soft steel slowly cooled, it segregates in relatively large masses, and crystallizes in polyhedric grains.

2. In steel of medium hardness, which has been slowly cooled from a high temperature, the ferrite, present only in small quantity, forms a membrane of varying thickness enveloping the grains of pearlyte. A section cut at any angle will, therefore, exhibit a network structure, the pearlyte forming the meshes.

3. Ferrite forms a structural element of pearlyte, which, as will be seen, is made up of an intimate mixture of ferrite and cementite.

Cementite is iron combined with cement-carbon—*i. e.*, carbon as it exists in unhardened steel. It is a carbide answering to the formula Fe_3C.

Like ferrite, cementite occurs:

1. In segregated masses, in very hard steels, but it always remains structureless.

2. As a very thin membrane, around the grains of pearlyte, when present in small quantities and under certain conditions.

3. As a structural element of pearlyte.

Pearlyte, as already stated, is not, strictly speaking, an elementary constituent of steel, being an intimate mixture of ferrite and cementite. A magnification of at least 300 diameters is required to resolve its structure.

The structure of unhardened steel is explained as follows: The carbon present in the steel unites with a portion of the iron to form Fe_3C, or cementite. The ferrite (*i. e.*, the remaining iron) and cementite then unite structurally in definite proportions to form pearlyte, leaving, as the case may be, an excess either of ferrite or of cementite, the former in soft steel, the latter in highly carburetted steel. With about 0.80 per cent. of carbon, the steel is entirely made up of pearlyte. It is then said to be "saturated."

Martensite is that constituent which exists at a high temperature, and being retained by sudden cooling, confers hardness upon quenched steel. About its true nature we know very little, having no direct evidence of its real composition. It contains iron and carbon, but not, like pearlyte, in definite proportion.

To sum up, all unhardened steels are composed of pearlyte alone, or pearlyte associated either with ferrite or cementite. All hardened steels are composed of Martensite alone, or Martensite associated with ferrite or cementite. The author then proceeds to describe the microstructure of steels quenched above, during, and below the critical range. He selected six samples containing respectively 0.09, 0.21, 0.35, 0.80, 1.20, and 2.50 per cent. of carbon. Several bars of each series were heated well past the critical range and allowed to cool partially before quenching, one bar being quenched above the upper critical point, another between the first and the second critical points, the next between the second and the third, and the last below the third or lower retardation.

The author's purpose was to ascertain in this way whether there were any perceptible structural changes corresponding to the critical points, and, if any, to determine their nature. He also took 21 bars of steel containing 0.21 per cent. of carbons, which he heated to 970° C. and allowed to cool to a series of points near and *within* the critical range, and from which temperatures they were suddenly cooled. In this manner some of the bars were quenched *during the retardations themselves*, thus revealing the progress of the corresponding structural changes.

The structures of the various samples were drawn from the microscope at a uniform magnification of 250 diameters and are reproduced in the paper. The areas covered by the micro-constituents were measured by means of the planimeter, in this way ascertaining the microstructural composition of each sample.

Upon the evidences furnished by the above investigations the author based the following important proposition: *Each critical point is accompanied by a structural change which begins and ends with it. In the ranges of temperature where there is no critical point, we find no change in the microstructural composition.*

Assisted by the microscopical evidences presented at length in the first part of the paper, the author proceeds to review critically the various theories which have been advanced to explain the hardening of steel and which he calls respectively, the carbon theory, the allotropic theory, the carbo-allotropic theory, and Professor Arnold's sub-carbide theory.

The *carbon theory* he considers somewhat crude and incomplete, attributing, as it does, in a vague manner, the hardening of steel to the existence at a high temperature of carbon in a hard state, and to its retention by sudden cooling. If the theory implies that it is to the carbon as such that quenched steel owes its hardness, is it not difficult to understand how, say 0.50 per cent. of carbon, be it as hard as it may, can produce the glass-like hardness of a steel of this composition when suddenly cooled above the critical range?

In the *allotropic theory* so ably worked out by Mr. Osmond and supported by Professor Roberts-Ousten, the hardening of steel is attributed to the retention in the suddenly-cooled metal of a hard allotropic state of the iron. To reconcile with their theory the fact that the degree of hardness produced by sudden cooling is roughly proportional to the amount of carbon, the allotropists argue that the carbon assists the retention of iron in its hard allotropic state. Such reasoning, says the author, cannot well be refuted, but it lacks cogency, and in some way predisposes us against the allotropic theory.

The allotropists contend that above the upper retardation the iron exists in a hard allotropic state called γ passing to another hard allotropic condition β during the first critical point and to the soft normal state α during the second critical point. The author asked how, if such is the case, the hardness of steel quenched between the second and third retardation, is to be explained, seeing that the metal in this range of temperature contains only soft α iron.

When heated to a high temperature, steel loses its power of being attracted by a magnet, from which it is argued that while α iron is magnetic, β and γ irons are not magnetic—suddenly cooled steels, however, are magnetic. This, the allotropists contend, is due to the fact that a portion of the non-magnetic β or γ iron passes back to the magnetic α state, however rapid the cooling. But then, since the more carbon present in the steel, the less α iron should be found in the quenched metal, high-carbon steels should be considerably less magnetic than mild steels, while, as a matter of fact, they are more magnetic. Again, from the fact that manganese steel, when slowly cooled, does not exhibit any critical point, and is both hard and non-magnetic, the allotropists conclude that manganese, when present in considerable quantity, prevents the passage of iron from the hard, allotropic variety to the soft α state. Since manganese steel is non-magnetic, it cannot contain any α iron, and should, therefore, acording to their theory, be harder than quenched carbon steel; but on the contrary, it never approaches the extreme hardness of high carbon steel suddenly cooled.

The author thinks that the two strongest arguments which have been put forward in favor of the allotropic theory are, first, the appearance and disappearance of magnetism, which corresponds to the reversible changes taking place during the second retardation; and, second, the fact established by Professor Roberts-Austen that nearly carbonless iron have two critical points.

The *carbo-allotropic theory* has been proposed by Mr. Howe. It attributes the hardening of steel to the existence at a high temperature, and to its retention by sudden cooling, of a carbide of an allotropic form of iron. In his *sub-carbide theory*, Professor Arnold ascribes the hardening of steel, not to the carbon as such, but to the existence above the critical range of a very attenuated and very hard carbide of iron, $Fe_{24}C$. According to Professor Arnold such would be the composition of Martensite, but the author has shown conclusively that Martensite contains all the way from 0.12 to 0.90 per cent. of carbon, according to the grade of the steel and the temperature from which the same has been quenched. It cannot, therefore, be a chemical union, in constant proportions of carbon and iron, as Professor Arnold would have it.

To further establish the existence of his sub-carbide, Professor Arnold presents the fact that a piece of steel containing about 0.90 per cent. of carbon (which is the amount of carbon required by the formula $Fe_{24}C$) evolves more heat during the lower retardation (which retardation is due, according to the theory, to the dissociation of the sub-carbide) than a piece containing less carbon or more highly carburetted. The author contends that the phenomenon has no bearing whatever upon the existence of a sub-carbide, being merely due to the fact that when the steel contains about 0.90 per cent. of carbon the *whole mass* changes its structure and possibly its chemical composition, while with a softer or harder steel only a portion of the total volume is affected in this way.

Professor Arnold says that the second critical point marks the passage of iron from a "plastic" to a crystalline condition. From this it must necessarily be inferred that above that point the structure of iron is amorphous. Mr. Osmond's and the author's microscopical investigations, however, have shown that the size of the crystals or grains increases directly with the temperature from which the metal cools, and inversely with the rate of cooling; whereas, if Professor Arnold were right, since the structure remains amorphous until the second critical point is reached, it would make little difference how far above this point the steel were heated; provided it were heated above it, it would always have the same sized grains. Again, steel quenched above that point has a decided crystalline structure, while, according to Professor Arnold, it should be amorphous. Indeed, is it not quite certain that crystallization sets in as soon as the metal is allowed to cool undisturbed, no matter how high the temperature? Can we conceive of a molten mass solidifying and remaining amorphous during cooling for a considerable time until a certain critical point is reached, when it crystallizes quite suddenly? Is not solidification in some way a synonym of crystallization, and, with one or two exceptions (like glass and opal), is there in nature any substance which solidifies without crystallizing?

While the contention that steel remains amorphous *during undisturbed cooling* is quite untenable, we have conclusive evidence that the metal becomes amorphous during the critical range, and strong indications that it *remains so during heating.* For if a piece of steel slowly cooled from a high temperature, and therefore presenting large crystals or grains, be reheated just above the critical range and again allowed to cool, we find the structure made up of very small crystals. The steel has evidently become amorphous during the retardation, and we cannot conceive of its crystallizing again during further heating. The fact that steel cannot remain amorphous during cooling, but does remain so during heating, may at first appear somewhat startling, but is it opposed to the laws which govern the formation and growth of crystals? Does not a falling temperature promote the formation of crystals; indeed, is it not a necessary condition to their formation? Does not a rising temperature, on the contrary, oppose it? During undisturbed cooling cohesive attraction acts powerfully, causing the crystals to grow. During heating, on the contrary, cohesive attraction is opposed more and more vigorously by the rising temperature, which finally destroys the crystalline arrangement and causes the structure to become amorphous. In other words, can crystallization take place during heating?

There are many phenomena in the physics of steel which cannot be accounted for by the theories advanced, and in the presence of the confusion which so much speculation is likely to throw on this subject, it is of great importance to keep carefully in mind the facts which have been proved beyond reasonable doubts. They may be classified as follows:

1. Carbon-steels during cooling or heating present one or more critical points or retardation. The retardations on heating are the reversals of the corresponding retardations on cooling—*i. e.*, one cannot take place unless the other has been induced since the former last took place. They are, therefore only the opposite phases of the same phenomenon. Very mild steels have three such retardations; mild and medium hard steels have two retardations; hard steel only one. Ac_3 and Ac_1 occur at a temperature somewhat higher than Ar_3 and Ar_1, while Ac_2 and Ar_2 nearly at the same temperature.

2. When a carbon-steel is quenched from a temperature above the critical range it is hardened in a degree roughly proportional to the amount of carbon. When quenched below the critical range it is not sensibly hardened.

3. Carbon-steel heated above the critical range is non-magnetic; below the critical range it is magnetic.

4. When hardened steel is dissolved in cold dilute acids the greatest portion of its carbon escapes as hydro-carbons. When unhardened steel is similarly treated nearly all of the carbon is found in a residue corresponding to the formula Fe_3C.

5. Each critical point is accompanied by a marked change in the micostructural composition of the metal, and no such changes occur except at critical points.

6. Manganese-steel containing about 12 per cent. of manganese, does not show any marked retardation during slow cooling. It is both hard and non-magnetic.

Seeing that not only is every critical point accompanied by a change of microstructural composition, but also that each such structural change is accompanied by a retardation, the author asks whether it is unreasonable to infer that the absorption or evolution of heat which occur at the critical points are due to the structural changes themselves?

But can the hardening of steel be accounted for without calling in allotropy or the existence at a high temperature of a hard state of the carbon or of a hard carbide? In other words, how else can we explain the hardness of Martensite? The author ventures to suggest that its hardness (and hence the hardness of quenched steel) might be due to the carbide Fe_8C, which *is known* to be very hard and which on account of being distributed throughout the Martensite in a very minute state of division, may impart to it a much greater mineralogical hardness than it does to pearlyte, the component of unhardened steel, in which this per cent. segregates in relatively large masses.

The extremely minute state of divisions of the carbide Fe_8C in Martensite might also account for the volatization of its carbon, when hardened steel is dissolved in cold dilute acids, while the coarse grains or plates in which the carbide occurs in pearlyte remains unaffected when unhardened steel is similarly treated.

The author does not wish to advance any new theory. He only feels that these remarks may contain some element of truth which may help in solving the problem discussed in the paper.

The paper has been discussed at length by metallurgists and physicists of this country as well as of Europe, contributions having been received from such eminent authorities as Professor Arnold, of the Sheffield Technical School, England; Professor Howe, of Columbia University; Professor Sedebur, of the Freiberg School of Mines; Mr. Osmond, of Paris; Professor Roberts-Austen, of the Royal College of Science, of London, and many others. They all testify to the impartiality with which the author has approached this complicated and much disputed subject and to the clearness and exhaustiveness of his presentation.

CEMENT IN SEA-WATER.

THE BEHAVIOR OF HYDRAULIC CEMENTS IN SEA-WATER.

By Dr. William Michaelis.

(CONTINUED FROM PAGE 213.)

By means of appropriate additions, the whole of the excess of lime could be securely combined, and the mortar thereby converted into one very much less capable of reaction; this would then inevitably be shown very soon and very distinctly, not merely in the degree of durability, but in the strength. Thus the behavior of the mixed hydraulic cement in sea-water could not but form the truest touch-stone for my theory, and also be of the highest importance from the point of view of national economy. And, more especially, I was soon led in this direction by the task imposed by the Standing Commission for the Unification of Standard Methods of Testing Building Materials, viz., to devise a test for determining the action of sea-water on hydraulic mortars.

The action of sea-water on these mortars is mainly a chemical one. In order to arrive quickly at results in this direction, everything had to be excluded which would form an artificial hindrance to the action of the sea-water; it would therefore have been quite a mistake to expose to the action of the sea-water mortars impervious to water, or mortars which, by absorption of carbonic acid, had gained an external protective covering; on the contrary, thoroughly porous mortars had to be used, which would offer no hindrance to the reaction between the sea-water and the mortar. Otherwise, the attainment of results would be delayed, and thereby the value of the test would be lessened.

The solutions which I employed for these researches were as follows:

1. Artificial sea-water containing of salt per litre—
30 grammes chloride of sodium.
12 grammes sulphate of magnesium with 7 water (Epsom salts).
3 grammes chloride of magnesium ($MgCl_2$).
1 gramme sulphate of calcium with 2 water (gypsum).

The addition of carbonates of the alkalies was intentionally omitted, since there is no object to be gained by weakening the action of the sea-water; but in order to maintain a constant proportion of sulphuric acid, as in the sea, pieces of gypsum wrapped in linen were suspended in the water. The water was renewed at first daily, then weekly, after three months, monthly, and it was thoroughly stirred every day.

2. A saturated solution of sulphate of calcium with gypsum suspended in it.
3. A solution of 1 per cent. crystallized magnesium sulphate.
4. A solution of 2 per cent. crystallized magnesium sulphate.
5. A solution of 3 per cent. crystallized magnetized sulphate.
6. A solution of 1.3 per cent. crystallized sodium sulphate (Glauber's salt).

L. Vicat had already employed solutions of sodium sulphate, and recognized it as having a very powerful action on hydraulic mortars.

Fifteen years ago I found that a solution of calcium sulphate with only 0.127 per cent. of sulphuric acid (SO_3) completely destroyed neat, and therefore absolutely impervious, Portland cement ("Stern" brand), and recognized thereby that only the sulphuric acid, not the magnesia, exerted an injurious influence on hydraulic mortars in sea-water, and that the magnesia was merely an accompanying phenomenon, and one of the visible signs of this destruction; indeed, that rather it was useful, and hindered the destruction by closing the pores during its separation in a nascent state.

It may, however, be easily understood why the action of magnesium sulphate must be much more energetic than that of calcium sulphate; this latter can only give occasion for the formation of the double compound of calcium alumino-sulphate, but the other changes also into gypsum the whole of the free lime with which it can react, and indeed, very probably, also the loosely combined lime of the highly calcareous compounds. It is only necessary to consider that at least a third of the whole of the cement used changes into calcium sulphate with two equivalents of water, and no other result can be looked for than the expansions and destructions on a grand scale, which are all too often exhibited by cement mortars in sea-water.

But a solution of calcium sulphate decomposes also Portland cements rich in alumina just as completely, and it has been favorable circumstances alone—impermeability, carbonic acid absorption, incrustations and closing of the pores by the process of the decomposition itself—that have kept the greater number of marine constructions which have been carried out with these highly calcareous mortars from complete and speedy ruin.

I had sent the foregoing remarks on October 25th, 1893, to the Institution of Civil Engineers, London, for incorporation in its Minutes of Proceedings as the second part of my paper "On the Behavior of Portland Cement in Sea-Water" (paper No. 2592, vol. cvii, session 1891–92); since, however, this work was too late for the session 1893–94, I withdrew it, and extended and completed it with experimental examples, which I now proceed to give. There were in the main two series of tests carried out, or rather entered upon; in the first place, one with close-grained mortar, viz.: 1 part by weight of cement to 2.5 parts of mixed-grained quartz sand, and also with mixtures of 1 part by weight of cement and 4 parts of standard sand; secondly, one with porous mortars, more especially of the proportion 1 : 5.

For the first series of tests there were prepared "Bauschinger" bars of 10 centimeters length and 5 square centimeters rectangular section from the following mortar mixtures:

1.	4	parts by weight of	Portland cement, “Stern” brand, with less than 6 per cent alumina,	
	10	“	quartz sand;	
2.	2	“	the same cement,	
	2	“	trass from Plaidt,	
	10	“	quartz sand;	
3.	4	“	the same cement,	
	1.2	“	hydrated silica (air dried),	
	13	“	quartz sand;	
4.	4	“	the same cement,	
	1.1	“	kaolin from Zettlitz, which has been heated to redness,	
	12.7	“	quartz sand;	
5.	4	“	Portland cement with about 9 per cent. alumina (from washed raw material),	
	10	“	quartz sand;	
6.	2	“	the same cement,	
	2	“	trass from Plaidt,	
	10	“	quartz sand;	
7.	4	“	the same cement,	
	16	“	standard sand;	
8.	4	“	the same cement,	
	1.2	“	hydrated silica as for 3,	
	13	“	quartz sand;	
9.	4	“	the same cement,	
	1.1	“	kaolin heated to redness as for 4,	
	12.7	“	quartz sand;	
10.	4	“	Portland cement with about 9 per cent. alumina (prepared by the dry process),	
	10	“	quartz sand;	
11.	2	“	the same cement,	
	2	“	trass from Plaidt,	
	10	“	quartz sand;	
12.	4	“	the same cement,	
	16	“	standard sand;	
13.	4	“	the same cement,	
	1.2	“	hydrated silica as for 3 and 8,	
	13	“	quartz sand;	
14.	4	“	the same cement,	
	1.1	“	kaolin heated to redness as for 4 and 9,	
	12.7	“	quartz sand;	
15.	100	“	Bavarian Roman cement,	
	36	“	water;	
16.	4	“	the same Roman cement	13 water;
	10	“	quartz sand	
17.	100	“	Bosnian Roman cement,	
	36	“	water;	
18.	4	“	the same Roman cement (17)	13 water;
	10	“	quartz sand	

19.	4	parts by weight of	lime from Teil,
	12	"	standard sand;
20.	4	"	lime from Teil,
	20	"	standard sand;
21.	5	"	hydrated silica as for 3, 8, and 13,
	12.5	"	slaked marble-lime with 32 per cent. residue on ignition.
	20	"	quartz sand;
22.	6	"	kaolin heated to redness as for 4, 9, and 14,
	16.5	"	slaked marble lime as for 21,
	28.5	"	quartz sand;
23.	4	"	anhydrous silica (hydraulic silica heated to whiteness),
	19	"	slaked marble lime as for 21 and 22.

All the bars made with these mortars were allowed to harden for the first twenty-four hours in moist air, but protected from carbonic acid; one-half of the bars were then placed in gypsum solution, kept constantly at the point of saturation in hermetically closed flasks; the other half were kept also in hermetically closed flasks, but in a one per cent. solution of magnesium sulphate. This solution was renewed during the first fortnight daily, then to the end of three months weekly, and after that monthly.

In the gypsum solution occurred:

	The Commencement of the Destruction.	Complete Destruction.
Mortar No. 1,	after 6 months	after 1 year
" 5,	" 6 "	" 1 "
" 7,	" 3 "	" 9 months
" 10,	" 3 "	" 9 "
" 12,	" 3 "	" 6 "
" 20,	" 1 year	
" 22,	" 14 days	" 1 "

All the remaining mortars are, at date—*i. e.*, after two years—quite intact.

In the one per cent. magnesium sulphate solution occurred:

	The Commencement of the Destruction.	Complete Destruction.
Mortar No. 1,	after 6 months	after 1 year
" 5,	" 6 "	" 9 months
" 7,	" 4 "	" 6 "
" 10,	" 3 "	" 9 "
" 12,	" 3 "	" 6 "
" 17,	" 18 "	
" 20,	" 12 "	
" 22,	" 8 days	" 1 "

From these tests it appears that the mortar No. 22 from kaolin and slaked lime is very quickly destroyed, both in gypsum and Epsom salts solution, while in fresh water it remains perfectly sound. For this there are two reasons: In the first place, kaolin heated to redness is a very loose puzzolana, and therefore furnishes, although a water-tight mortar, yet one that has but little density; secondly, kaolin is the puzzolana which is richest in alumina, for its composition is 55 parts by weight of silica to 42 of alumina in every 100.

The mixture of 6 parts by weight of kaolin and 16.5 of marble lime contained, moreover:

3.30	parts by weight of silica,	or in equivalents,	550
2.52	" " alumina,	" "	244
5.28	" " lime,	" "	943

so that there could almost exactly be formed $SiO_2CaO + 2Al_2O_3, 3CaO$. The aluminate is here the sole cause of the destruction; that this sets in so quickly is explained by the high proportion of alumina. We have seen above that one part by weight of alumina goes to form nearly 12 times its quantity of the calcium alumino-sulphate with 30 equivalents of water, but the mortar from kaolin and slaked lime has 22.7 per cent. alumina, and from that 270 parts by weight of the double compound can be produced.

Notwithstanding this, the three mixed mortars of Portland cement and kaolin are—indeed, contrary to expectation—still well preserved (after two years), this being evidently entirely due to the binding of the free lime by this addition.

The unmixed Portland cements have gone quickly to pieces, the two containing 9 per cent. alumina more quickly than the "Stern" cement with only 5 per cent. to 6 per cent. alumina, exactly as theory might predict. The lime from Teil has until now remained well preserved; the more porous mortar 1 : 5, which was protected whilst hardening against carbonic acid absorption, shows in one of the bars a commencement of the destruction at the most sensitive point, viz., at the corner.

The Bavarian Roman cement, both "neat" and as 1 : 2.5, has remained perfect to this hour; in the case of the Bosnian Roman cement, the destruction began in the magnesium sulphate solution at one of the corners after eighteen months; the sand mortar of this cement is still completely intact.

The composition of these two Roman cements, after thorough ignition, was:

	Bavarian. Per Cent.	Bosnian. Per Cent.
Sand and clay, ... =	6.381	2.920
Silica, ... =	23.881	30.180
Alumina, ... =	9.709	9.036
Oxide of iron, ... =	4.052	3.669
Lime, ... =	47.229	49.000
Magnesia, ... =	3.992	2.215
Sulphuric acid, ... =	4.237	2.109
Manganese, Alkalies, } . . . . =	not estimated	not estimated
	99.481	99.129

As shown above, the highest compounds, or those richest in lime (as set forth at the commencement), cannot be formed in these two cements in the process of hydraulic hardening; if the formation of $2R_2O_3$, $3CaO$ be assumed, there remains in the Bavarian cement 1.5 equivalent of lime for the saturation of the silica, in other words the compound $2SiO_2$, $3CaO$, and in the Bosnian cement 1.35 equivalent of lime, or the compound $3SiO_2$, $4CaO$. This explains why these Roman cements withstand the action of the sea-water so well.

But long before visible signs of the destruction through the sea-water make their appearance, the injurious action, or, in the contrary case, the absence of injury, must be revealed by tests of strength, and more especially by comparative tests of strength with fresh and sea-water hardening, and it was thus a way was found to the method of testing the influence of sea-water.

It is obvious that such briquettes will be the most suitable for experiments of this nature as have a large surface in proportion to the section to be tested; *e. g.*, bars such as are employed for testing bending strength, and for which I have adopted the following dimensions: Length =30 centimetres, breadth=4 centimetres, height=2 centimetres, width of span 21.33 centimetres, minimum tension in kilogrammes per square centimetre $=2\times P$, whereby therefore the doubled breaking weight gives the breaking strength per square centimetre, and for which the ordinary standard testing apparatus, with double-lever system $1:10\times 1:5=1:50$, is used. Or the well-known fiddle-shaped briquettes (Achter) for tensile tests with 5 square centimetres section (Fahnehjelm'-Michaelis' standard mold) are very suitable. These last, moreover, can, after breaking, be tested for compression strength, being put together again and held thus with an elastic band. As has been already stated, there would be no object in testing the influence of sea-water on hydraulic mortars by means of impervious mortars, for thereby the result would only be delayed and the testing therefore made much more troublesome, and its value materially diminished; methods of testing obviously excel according as they lead quickly to the desired end. For this reason mortars of 1 part by weight of cement to 5 of sand are much to be preferred.

It was with this fact in view that I arranged the second series of tests, which, however, is not yet quite completed. There were employed the same Stettin Portland cement (A), the same Portland cement with 9 per cent. alumina, and made by the dry process (B), the same lime from Teil (C), and the same Bavarian Roman cement (D), which had served for the first series of tests. The analyses of these cements showed the following composition in a freshly ignited state:

	A.	B.	C.	D.
	per cent.	per cent.	per cent.	per cent.
Silica, ... =	21.712	21.331	23.88	23.881
Alumina, ... =	5.805	8.918	2.57	9.709
Oxide of iron, ... =	2.949	2.695	0.88	4.052
Lime, ... =	64.851	63.776	69.15	44.263
Magnesia, ... =	1.030	0.805	1.60	3.992
Potash, ... =	0.748	0.777	0.14	
Soda, ... =	0.160	0.101	0.07	
Sulphate of lime, ... =	2.468	1.631	1.09	7.203
Insoluble matter, ... =	0.357	0.123	. . .	6.381
	100.080	100.157	99.38	99.481

The mortars were made into tensile test briquettes in accordance with the (German) regulations, 1 part by weight of cement and 5 of Berlin standard sand being used.

Artificial sea-water was employed of the composition given on page 228. The briquettes were left to harden—except as otherwise noted—during the first 24 hours in air saturated with moisture in a closed space. Those which are indicated by the letter "M" were immersed in sea-water in an upright position; those indicated by "S" were immersed in fresh water. Those under "Ma" were, for eight weeks before immersion in sea-water, kept exposed to the air, and daily sprinkled with water for the absorption of carbonic acid.

Age from Time of Immersion.	AS.	AM.	AMa.	BS.	BM.	BMa.	CS.	CM.	CMa.	DS.	DM.	DMa.
7 days .	103	85	227	150	112	243	54	70	110	40	89	187
28 " .	144	107	217	181	97	253	73	92	99	73	131	192
90 " .	165	148	218	214	130[1]	227	119	155	141	138	163	209
1 year .	228	228	92 *bis* 257	238	160[2]	28 *bis* 214	189	217	178	206	201	220

The briquettes of the lime from Teil hardened first for 28 days in the air in a closed damp space; then (in the case of "CMa") for eight weeks in the air, with daily sprinkling for carbonic acid absorption. The testing term counts from one day before the immersion; thus, in the case of those briquettes indicated by "Ma," the immersion in sea-water took place only after eight weeks, those under "CS" after four weeks, and those under "CMa" after twelve weeks. The briquettes have now been under treatment 20 months.

The figures in the annexed tabulated results of the testing represent pounds per square inch, and are in every case the mean of 10 single tests.

The cement "A" was now mixed with Plaidt trass (tufa); with regard to this—as also to the mixtures of the first series of tests—the following may be noted:

100 parts by weight of the trass from Plaidt contain—
 10 to 12 parts water and loss on ignition,
 20 to 30 parts hydraulic silica and alumina,
 60 to 65 parts minerals which act like so much sand.

The trass employed left on the sieve with 2,500 meshes per square centimetre (16,000 per square inch) 41 per cent. residue, and had the following composition in an air-dried condition:

	Per Cent.
Hygroscopic water,	4.141
Chem. combined water,	6.899
Loss at 900 deg.,	0.202
Silica,	53.583
Alumina,	19.008
Oxide of manganese,*	0.115
Oxide of iron,*	4.193
Lime,	1.736

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* Iron and manganese were calculated as peroxide, although protoxides of these occurred in the trass.

	Per Cent.
Magnesia,	= 1.652
Potash,	= 4.147
Soda,	= 4.242
Titanic acid, Chlorine, Phosphoric acid,	not estimated
Sulphuric acid,	= 0.107
	100.025

With 10 per cent. caustic soda solution this trass gave—(*a*) Digested 10 hours on the water bath; hydraulic silica = 16.543 per cent.; hydraulic alumina = 4.810 per cent. (*b*) Digested 24 hours on the water bath: hydraulic silica = 16.708 per cent.; hydraulic alumina = 6.043 per cent.

The two following mortar mixtures were prepared:

	1	part by weight,	cement A	1.25 binding material	therefore rather richer than 1 : 4.
E.	1	" "	Plaidt trass		
	4	" "	standard sand	4.60 sand	
	1	" "	cement A	1.125 binding material	therefore rather poorer than 1 : 4.
F.	0.5	" "	Plaidt trass		
	4.5	" "	standard sand	4.800 sand	

Here also "S" represents fresh water, "M" sea-water immersion. The figures represent pounds per square inch, 10 separate tests in each case:

AGE.	ES.	EM.	FS.	FM.
7 days, ...	140	168	157	144
28 "	273	400	241	279
90 "	381	510	311	337
1 year, ...	442	564	393	351

It had been shown that, out of 100 parts by weight of Portland cement with a medium proportion of lime, about 25 parts CaO, equivalent to 33 parts CaH_2O_2, become free. On admixture of 100 parts by weight of trass, which, for example, contain 16.5 parts silica and 5.14 parts alumina capable of combination, the formation of SiO_2 CaO would require 15.4 parts CaO, and that of $2\ Al_2O_3$, 3 CaO would require 4.2 parts CaO, or together 19.6 CaO; thus there may be formed a silicate richer in lime than the single silicate, and it is therefore very probably advisable to mix 125 parts by weight and more of trass, with every 100 parts Portland cement; moreover, compounds of $2\ SiO_2$ to 1 to 2 CaO become exceedingly hard, and are quite certainly still more stable than the single silicate. In any case, the addition should be higher in proportion according as the cement is richer in lime; this applies equally to hydraulic mortars.

"FM" shows, after a year's interval, that even here the injurious action of the sea-water is making itself felt; for, in the case of this mixture of 100 cement and 50 trass, only about 10 parts by weight of the lime becoming free could be completely laid hold of, and there would still be 15 parts by weight of lime capable of reaction so to speak, and, even if the silicate 2 SiO_2 2 CaO, and the aluminate 2 Al_2O_3 5 CaO were formed, 10 parts by weight of calcium oxide would still remain free for reaction with the sulphates of the sea-water.

Later experiments, begun only in October, 1895, have reference to mortar mixtures of Portland cement and lime from Teil, with the addition of trass in such proportions that the mortar, through addition of the trass, becomes, in view of the quantity of binding material which this last supplies, not richer but rather poorer, and, therefore, more porous. The composition of these mortars is as follows:

G. Portland cement with 9 per cent. alumina (as in B above) 1 : 5 Berlin standard sand;

H. Of the same cement 1 part by weight to 1 part by weight of trass and 6 of Berlin standard sand;

I. Of the same cement 1 part by weight to 1 part by weight of trass and 6.75 of Berlin standard sand;

K. Teil lime (as in C above) 1 : 5 Berlin standard sand;

L. Of the same lime 1 part by weight with 1 part by weight of trass and 5 of Berlin standard sand;

M. Of the same lime 1 part by weight with 1 part by weight of trass and 6 of Berlin standard sand;

In H to every 1 part by weight of binding material there is nearly 5.3 sand.
In I to every 1 part by weight of binding material there is nearly 6 sand.
In L to every 1 part by weight of binding material there is nearly 5 sand.
In M to every 1 part by weight of binding material there is nearly 5.6 sand.
K, I, and M hardened first for seven days in the air, in a covered damp space.

The experiments to E to M are to extend over three years. The broken test-pieces of one year old and upwards will then be placed, some in 2 per cent., some in 3 per cent. magnesium sulphate solution, and thereby exposed to a very much more energetic attack than they would be in the strongest sea-water.

The results of the strength tests obtained till now are as follows—every figure being again the mean of 10 single tests, and representing pounds per square inch.

Δ gives the density of a unit of mass of one cubic centimetre immediately before the breaking. S and M represent fresh-water and sea-water hardening respectively.

Age from time of Immersion.	GS.	GM.	HS.	HM.	IS.	IM.	KM.	LM.	MM.
28 days . . .	125	90	148	309	144	292	42	167	147
Δ . . .	. . .	. . .	. . .	. . .	. . .	. . .	2.162	2.195	2.227
90 days . . .	146	107	240	350	236	351	34*	308	287
Δ . .	2.137	2.172	2.26	2.28	2.274	2.292	2.252	2.250	2.259

On an examination of the above strength test results, it is at once apparent that sea-water exerts on all mortars, which contain lime becoming liberated, an influence which is opposed to increase of strength; two processes strive one with the other, the hydraulic hardening process and the crystallization process, and as a rule the latter obtains the mastery in this fight, and causes the complete destruction of the cohesion at first gained through the hydraulic process.

Of the briquettes BM, one showed, even after ninety days' visible signs of destruction; it was decomposed and split up in such a way that it broke in being fixed in the machine; in the fracture the deposition of magnesic hydrate showed itself for some millimetres in depth. In the case of the testing at one year, all briquettes, with one exception, showed this deposition of magnesia in progress to a depth of five millimetres; the same was observed in the case of BMa. In regard to this, it is remarkable that the briquettes which had been subjected to carbonic acid absorption were even more quickly destroyed,† the carbonated scale being raised up and rolled over, as distinctly shown in AMa as contrasted with AM, and in CMa as contrasted with CM after one year; DMa is the only exception to this; all the test-pieces of D were perfectly sound, and showed besides, in the fractures, not the slightest separation of magnesia.

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* The 90-day test briquettes of Teil lime, without addition, showed, apart from the retrogression in strength, in certain places some "blowing" of the outer scale.

† An explanation of this fact may perhaps be found in the circumstance that the mortar becomes, through the carbonic acid absorption, more porous, and therefore more accessible to the entrance of the saline solution, so that this latter can make its way more easily to the interior portions. The hydrosilicate of lime, at least, is in the colloidal state. Decomposed by the carbonic acid, crystalline carbonate of lime will be formed, and the silica will shrink together; with a colloidal condition to start with, this carbonating process must, obviously, produce a much less dense mortar.

The figures speak for themselves; the admixture of trass (and of puzzolanas in general) with over-limed hydraulic binding agents, Portland cements, and hydraulic limes, is capable of raising the strength of mortars made with these to two or three times what it would otherwise be, and to make these materials permanently sound in sea-water. As regards the increase in strength, this is, indeed, clear at a glance; the best puzzolanas contain at least as much of the hydraulic factors as the best Portland cement; therefore, it cannot but be that, from the union of these materials, a hydraulic mortar of redoubled strength results, since Portland cement contains a sufficient excess of lime to admit of the puzzolana attaining its full size.

Obviously those mixtures which are rich in hydraulic silica and poor in alumina are the best, and, for this reason, the addition of kaolin for marine constructions is not to be recommended.

It may then be with confidence asserted that evidence has been furnished, both scientifically and practically, that hydraulic binding agents, which contain more lime than is sufficient for the formation of stable hydrosilicates and hydroaluminates (and only the compounds poor in lime are to be recognized as stable, and that in a higher degree according as they are poorer in lime) may not be employed for marine constructions.

Since then, according to my proposal, mixed cements furnish a mortar not only much more durable and strong, but also considerably cheaper, it is in the interest of the public welfare that these mixed cements should be as widely used as possible, and that, our knowledge of these things being now extended, and the real cause of the danger distinctly recognized, the employment for marine constructions of hydraulic binding materials too rich in lime, without improving additions, should no longer be permitted.

The solution of the problem is, moreover, the most favorable that could be imagined; the old methods still hold good; all we have to do is to make a sensible use of the ancient, most effective, and, at the same time, cheapest hydraulic mortar formers, amongst which none takes a higher place than genuine trass. By "genuine trass" is meant the finely-ground tufa (trass-stone), without any admixture of ashes or other substance. Since, however, they are associated here with the strong, energetically hardening Portland cement, the other varieties of puzzolana, which possess a smaller degree of initial energy, are also quite available.

A purely theoretical computation, as well as also practical, quickly effected tests, show readily, in every instance, what mixtures are the best.

No combination should offer greater advantages in every way than that of trass (or puzzolanas similar to trass) and Portland cement, for no mortar mixture can excel this in respect of price and strength, initial energy, and power to withstand the destructive influence of the sea-water.

That the employment of Portland cement would suffer thereby is just as far from the fact as was formerly the groundless fear that road traffic would decrease owing to the making of the railways; as was the case there, so here also the very opposite will occur.

The *a priori* predicted improvement* of hydraulic cements rich in lime through suitable additions of substances containing (hydraulic) silica (and alumina) capable of combination, which had already been fully proved in the case of hardening in fresh water, has now found a confirmation surpassing anything that could have been expected in the case of hardening in sea-water; a confirmation which has brought to shame the completely false representations of the Council of the German Cement Makers' Association in its report of the year 1882 to the Prussian Minister of Public Works.

How the consumer is to approach the question of admixture is not my affair, although I still continue to regard the matter from the same point of view, viz.: That the manufacturer is in the best position to effect the most appropriate admixture according to the special nature of the article made by him, and also, by means of his plant, to carry it out in the most thorough manner; for from the above expositions, it is clear that every hydraulic cement requires a different proportion of the material to be added, and that this is dependent, on the one hand, on the percentage of lime in the cement, and, on the other, on the percentage of the effective hydraulic factors in the added substance. This question, is, however, one to be settled by public bodies concerned in the consumption, experts, etc.

Doubtless this work would have been of still greater value had I postponed for some years the publication of it; but my now comparatively advanced age, and the consideration of the marine constructions on a grand scale which are about to be taken in hand by many different civilized States, and in which millions of capital will be involved, have induced me to make known the results of my researches without further delay. Scientific and practical men may now repeat my work, subject it to the keenest tests, and along with myself extend and complete it.

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* See my paper "Zum Dogma von der Unmöglichkeit, etc.," 1894.

In my first treatise on the "Behavior of Portland Cement in Sea-Water," which I had the honor to submit to the Institution of Civil Engineers (Paper No. 2,592, vol. cvii, Session 1891–92, Part I), I suggested at the close the use of some auxiliary substances which should have the effect on the one hand of stopping, as completely as possible, the pores of the outer layers of mortar exposed to the action of the sea-water, and on the other of filling them with saturated compounds, or with such compounds as could not react further with the sulphuric acid salts of the sea-water, nor crystallize with these with increase of volume. Such auxiliary materials are indeed very valuable, but their employment is not always easy or certain.

My present proposal goes at once to the root of the evil by laying hold, at the outset, of the injurious excess of lime, and converting it to a useful purpose; this proposal is based upon the fact which I have long upheld, that clinkered Portland cements, too high in calcic oxide, and hydraulic limes, may—either in the process of manufacture, or in the preparation of the mortar—be improved, and more especially rendered more capable of withstanding the decomposing action of sea-water, by means of such additions as will go to form fresh hydraulic mortar with the excess of lime or with that which is set free during the hardening process, *i. e.*, with puzzolanas, in the widest sense of the word. Such suitable puzzolanas are: Hydraulic silica itself, opal, infusorian earth, puzzolanas in the more restricted sense, trass, Santorin earth; also, further, powdered glass, certain granulated blast furnace slags, burnt alum-shale, kaolin, brick dust, etc.

Of all known additions of this kind, the most effective is real trass, on account of the high proportion it contains of the hydraulic factors, and of the excellent quality of that portion of it which acts as sand.

The mode of testing hydraulic cements as to their fitness for marine structures may be readily deduced from what has been stated above.

The proposition made by me to the Standing Commission for the Unification of Methods of Testing Building Materials, in regard to the testing of hydraulic binding agents for their behavior in sea-water, runs thus:

"The testing for power to withstand the action of sea-water is carried out with porous mortars (1 : 5), whether for tensile, compression, or flexion strength, with immersion in artificial or natural sea-water, which is renewed during the first twenty-eight days daily, and thereafter weekly, and which is daily stirred.

"As artificial sea-water is reckoned a solution, which in a litre of water contains:

30 grammes sodium chloride,
3 " magnesium chloride (calculated as anhydrous),
3 " magnesium sulphate (calculated as anhydrous),
1.25 " calcium sulphate (calculated as anhydrous),

bicarbonates are omitted, since there is no object to be gained by retarding the action of the sea-water; on the contrary, bars of gypsum, wrapped in linen, are placed in the artificial sea-water in order to keep constant the proportion of sulphuric acid—as in the sea itself.

"*Rationale.*—The action of sea-water on hydraulic binding agents is chiefly a chemical one, proceeding from the reaction of the soluble phosphates in the sea-water on the free lime (or on that becoming free in the course of the hardening process), on the ferrate of lime, on the aluminate of lime, and on the silicate of lime, especially such compounds of these as are high in lime.

"In pervious mortars the amount of the action is most quickly determined, and that by the results of the strength tests. On this account are to be preferably recommended briquettes of 1 cement to 5 sand, and having a large external surface in proportion to breaking section. Briquettes for tensile and bending tests are to be preferred to those for compression tests.

"Comparative tests with sea-water and fresh-water hardening admit of a very speedy judgment being obtained as to the action of the sea-water.

"A solution of 2 per cent. crystallized magnesium sulphate leads still more quickly to the end in view.

"The 'action of the magnesium salts on hydraulic mortars' should no longer be spoken of, since the magnesia exerts no injurious, but rather a beneficial influence through closing of the pores (Colmatage); it becomes separated as a soft, loose hydrate, which causes no tension of any kind, is insoluble in water, and remains therefore where it separates. Only the sulphuric acid exercises a destructive influence, and, for this reason, all soluble sulphates act in the same manner, whether sodium (Vicat), or calcium sulphate (Michaelis), or magnesium sulphate."

With my theory of the year 1882 a seed was sown which has since, notwithstanding the most unfavorable circumstances, grown to a young tree which now bears fruit. It is my hope that this tree will continue to grow uninjured, and that, long after those who sought to poison its roots have played out their part and fulfilled their destiny, it will mightily spread abroad its branches for the benefit of coming generations. These very marine constructions subserve in a conspicuous manner the safety and welfare of mankind, and to have contributed to these latter in the smallest degree is in itself sufficient reward.

THE STREET RAILWAY SYSTEM OF GLASGOW is now entirely under the control of the municipality, the city recently having leased lines not already acquired. About 99,000,000 passengers were carried during the year ended May 31st, 1897. Had the rates prevailed during the year that were charged there years before the city assumed control of the lines the total fares paid during 1896–7 would have been more than $800,000 in excess of those actually paid. Notwithstanding this reduction in fare the city increased both the service and the wages of all classes of employés, paid interest and two per cent. to the sinking fund, over $40,000 to the "Common Good," some $60,000 depreciation, $70,000 to the permanent way renewal fund and placed nearly $100,000 in the general reserve fund. The last two funds now amount to over $350,000. The total receipts for the year were $1,780,000 from traffic and $25,000 from other sources, and the working expenses alone were $1,395,000.

TESTS OF VULCANITE PORTLAND CEMENT.—The nine months' tests of Vulcanite Portland cement, reported during the last month by Lathbury & Spachman, the chemists, shows an average tensile strength of 400 pounds, which makes a very good showing of increasing tensile strength of this very promising new brand of Portland cement. The previous tests show the following average: Seven days, 213 pounds; one month, 341 pounds; six months, 365 pounds; the first two with 11 per cent. of water, and the last two with 12 per cent.

COMPARISON OF LIME AND CEMENT MORTARS WITH REFERENCE TO THEIR APPLICATION IN CONSTRUCTION.

ALTHOUGH the superiority of cement over lime mortars is acknowledged in the United States, and cement is used in all masonry or other construction work which requires any excellence in strength or endurance, yet such is not the case in France. In speaking of this condition in the *Nouvelles Annales de la Construction* (March, 1896), M. E. Candlot says: "In France, where the art of construction has long since attained a high degree of excellence, there are some points in which it seems imperfect; we can attribute this in great part to ignorance of the properties of the most useful materials, and a contentment with general and vague notions, to give but one example—the nearly unanimous opinion that mixtures of lime and cement are bad because of the different setting properties of these materials. It does not require any very extended study to find that the pretended interference in setting and crystallization does not exist. The engineers, architects, and builders of Germany and Austria had no such notions; they appreciated the properties of such mixtures and especially of mortars of great strength. In France, however, it is hard to overcome the natural resistance to the adoption of new methods and ideas. Preference has even been shown to lime in some of the latest examples in construction, and one of the later treatises of a technical nature has advocated its superiority. Similar ideas, however, find their reward in such examples as the catastrophe at Bouzey (see *Le Genie Civil*, vol. XXVII, No. 19, p. 301). The greater price is an argument often advanced, although cement can be bought for $5.80 per metric tonne f. o. b. at works."

The advantages and superiority of cement can best be shown by practical tests; experiments have been made by many of the best engineers, among whom may be mentioned M. Batard, engineer of bridges and roads at Cette, whose observations extend over many years. He says: "The advantage of using mortars of great tensile strength is generally evident for all classes of work, but it is of special importance in work subject to bending and flexure and where its tensile properties are directly put into play as in ordinary masonry vaults or cisterns, the bottom of sluices or ditches, walls of dry docks, artificial concrete blocks placed along jetties, etc. In the last example the comparison of cost and strength of beton and masonry is very well marked. At Cette for example, lime costs $3.86 per tonne of 2,204.6 pounds, while cement costs $8.10; sand from the neighborhood costs 29 cents per cubic meter (= 1.3 cubic yards), while the Argeles sand used in cement costs $1.35 to $1.54. Under these conditions the comparison between masonry and beton, made in the proportions of 882 pounds of lime per cubic metre of Cette sand, and 1,103 pounds cement per cubic metre of Angeles sand, will give a cost of $1.45 for lime masonry and $2.12 for rich beton.

"But if one compares the strength of these mortars at different ages one is struck by the *enormous superiority of cement mortar over that of lime;* in a month the resistance of the first is equal to three or four times that of the second; in from three months to two years it is at least double. It possesses, hence, not only the great advantage of being quicker setting, but a much greater final strength, without counting the superior resistance of cement to the chemical action of sea-water."

In a work * published recently by M. Souleyre, engineer of roads and bridges at Constantine, and M. Anglade, superintendent of roads and bridges, we find some valuable information which is the result of many years of observations by very precise methods. They arrive at the following conclusions:

HYDRAULIC LIME.—"Our normal briquettes of 882 pounds lime per cubic metre of sand have given a test of 256 to 398 pounds per square inch. In the open air bricks did not attain the same strength as when immersed."

CEMENT.—"The strength of Portland cement mortar of 1,103 pounds cement to one cubic metre sand is nearly 50 per cent. more than the best lime mortar of 882 pounds kept in water. But it is specially superior for small periods of setting. In three weeks the strength reached to nearly its maximum, a point which the best lime mortar scarcely attained at the end of a year.

"Cement can be employed in proportions as low as 660 pounds, and will even then make a mortar much better than one of 882 to 992 pounds lime per cubic metre of sand, less than two years old,

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[*] *Experiences sur les Materiaux des Maçonnries:* Autographic L. Poulet, Rue de France, Paris.

and when kept in water for two or three years makes a mortar equal to the best lime mortar under similar conditions."

BETON, WITH HYDRAULIC LIME.—"The strength of beton hardened in water (882 pounds lime per cubic metre sand) is 142 to 156 pounds per square inch. The absolute resistance of beton kept in water of 882 pounds mixture is from 185 to 189 pounds per square inch. In dry air or with bad sand the strength becomes very small, and often nearly zero."

MASONRY, WITH HYDRAULIC LIME.—"We can say that the best limestone ashlar masonry mortar of 882 pounds mixture, kept under water, attained to a strength of 85 to 99 pounds per square inch. Masonry kept in air gave results from zero to 71 or 85 pounds per square inch."

BETON AND CEMENT MASONRY.—"The resistance of beton of 1,103 pounds cement per cubic metre of good sea sand reached 320 pounds per square inch, and broken ashlar masonry 200 pounds per square inch within 40 or 50 pounds either way. These tests were uniform in results, and accidents were extremely rare with briquettes of cement mortar."

RESISTANCE TO COMPRESSION.—"As in tension, beton of Portland cement mortar (1,103 pounds mixture) had a greater strength than that made from hydraulic lime. At thirty-five days, with blocks of 0.15 meter, we have found a resistance of 2,133 pounds per square inch in air where lime (882 mixture) gave but 540 pounds per square inch. In three months the comparative strength was the same, four times the lime beton. In three and one-half years the cement reached 2,560, nearly double the strength of that of beton of hydraulic lime. Cement mixtures behave as well in air as in water, and are therefore adapted for dry countries. The ultimate compressive strength of hydraulic lime beton at the age of three months was 185 pounds per square inch on the original surface, or 554 pounds per square inch on the surface remaining after crushing. In cement beton these figures become 711 and 2,133 pounds per square inch."

PRACTICAL DEDUCTIONS.—"The breaking of masonry is accompanied by extension or stretching of the stone or mortar before rupture takes place; with hydraulic lime this is quite small; with cement mortar there seems to be considerable elasticity. The final conclusions arrived at may be thus stated. Broken ashlar masonry (882 pounds hydraulic lime to one cubic metre good sand) can support at least 356 pounds per square inch compression. Cement mortar masonry (1,103 pounds cement to one cubic metre good sand) can support strains of 113.7 pounds per square inch tension and 995.6 per square inch compression. On account of its greater strength, cement mortar has the additional advantage of stretching less under the same load."

In some experiments made upon a bridge over the Rhone at Geneva, according to *La Construction Moderne* (Jan. 11th, 1890), we find that pure hydraulic lime briquettes gave a compressive strength of 1,422 pounds per square inch, while neat cement gave 5,688. Lime mortars gave but 711, and cement mortars gave 2,844, when the proportions of sand were the same.

If one were to deduce a general rule in round numbers, probably the following would be found adapted to builders' use: *The strength of cement betons and mortars is four times that made from hydraulic lime and its derivatives.* In many modern structures the building is finished before lime mortar can attain even to its calculated strength, so that a mortar is necessary which attains its maximum strength very soon.

THE IMPROVEMENT OF PORTLAND CEMENT BY ADMIXTURES.

By Dr. L. Erdmenger.

[Translated from *Thonindustrie Zeitung*, Berlin, Germany, 1896.]

THIS question has been put aside for a length of time principally on account of the influence of the stand taken by the Society of German Portland Cement Manufacturers, which treats good and valueless admixtures under one head. The impossibility of improving Portland cement by admixture has, however, never been fully proved, due regard to unbiased investigators. Many points have been unrefuted. According to the opinion of many, the zeal of the Society is, therefore, reaching too far. The troublesome fact, that in this categorical way, the *real* and the *doubtful* have been classified under one head, is unmistakably liable to cause erroneous impressions about the matter in question. Without stirring up the different instances of "for" and "against," I will to-day refer only to the experiments made by Mr. Albert Toepffer in the last general meeting, where he claims the most remarkable improvement in the "Stern" cement, through the addition of trass.

Besides, I will mention a series of experiments made abroad bearing on this question. An American friend, Mr. Andrew Lundteigen (a Norwegian by birth), in charge of the technical department of the Western Portland Cement Company, at Yankton, South Dakota, with whom I often correspond about questions appertaining to cements, has used some time to study the effect of admixtures in Portland cement. In a letter of April, this year, he gave me the results of a series of experiments, which, in March, comprised somewhat over a year. Mr. Lundteigen calls his mixing material "S." Like trass, it is found in nature all ready for use, but shall not here be characterized any further. I give the results, as in the original, in pounds per square inch.

TABLE "A."

				Another Sample.	
	Neat Cement.	1 Cement. 3 Sand.	1 Cement. 1 S. 3 Sand.	1 Cement. 2.5 Sand.	1 Cement. 1 S. 5 Sand.
7 Days, ...	419	77	33	89	40
28 "	554	136	100	163	125
180 "	847	264	341	[*]252	[*]314
335 "	950	298	470	[†]254	374

Mr. Lundteigen remarks about this: "Are not these results remarkable? My theory is that after a certain length of time the maximum strength of concrete is reached.[‡] Then forces commence to act, which injures the strength of the concrete, and is caused by an excess of lime. By adding the material 'S,' the lime combines with it in such a way that an expanding tendency is prevented."

From the above it is seen that this investigator also believes in the presence of free lime, a fact claimed by me as early as in 1879–1881, and later repeatedly by others, who have discovered crystals in hardened cement bodies, especially such made from neat cement. The leading members of the Cement Society have always overlooked this fact, and in their well-known declaration they do not admit the presence of free lime in Portland cement. From what reason, on the other hand, is not known. Mr. Lundteigen continues: "I make briquettes from 1 part slacked lime, 2 parts of the 'S' material, and 9 parts of sand; kept them in water at 100° F., and obtained at the end of seven days 35 pounds, and at 30 days 193 pounds; while the briquettes made from lime and sand without 'S' material had no strength whatever. My experiments show that it is only high-limed Portland cements which are much benefited by the addition of the 'S' material."

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[*] Four months old.

[†] Some cracks in the corners of briquettes. Each number is the average of three breakings.

[‡] This agrees with repeated experiments made by myself before, principally with rich mixtures.

Mr. Lundteigen gives still another series of tests, which are given in the tables I, II, and III. The capital letters indicate the initials of the different brands of cements. H, D, and S A are German brands; A P means American Portland cement; W K is an English and R C a Belgian cement:

TENSILE TESTS.

I.	Neat Cement.		1 Cement. 3 Sand.		1 Cement. 1 S. 6 Sand.	
	H.	A P.	H.	A P.	H.	A P.
7 Days, . .	566	464	175	129	52	27
28 " . .	800	601	223	183	92	92
80 " . .			215	248	131	151
180 " . .			294	293	248	213
	*737	*785	*287	*436	*305	*292

COMPRESSION TESTS.

II.	1 Cement. 4 Sand.		1 Cement. 1 S. 8 Sand.	
	D.	A P.	D.	A P.
7 Days, ...	445	282	218	167
28 "	767	603	441	320
80 "	1047	945	700	558
180 "	†309	1094	901	805
	‡836	‡1846	More than ‡2030	‡1804

* One day in air; 10 days in cold water; 10 days in steam boiler with pressure varying from 20 to 90 pounds per inch.

† Briquettes cracked.

‡ One day in air; 36 days in cold water; 10 days in steam boiler with pressure varying between 20 and 90 pounds per inch.

III.	Fineness.		Neat Cement.				1 Cement to 4 Sand.			
	50 Mesh.	100 Mesh.	7 Days.	28 Days.	6 Mos.	12 Mos.	7 Days.	28 Days.	6 Mos.	12 Mos.
H,	1.0	6.0	528	731	752	779	133	160	249	263
D,	1.0	6.0	523	785	806	803	108	173	192	*143
R C,	4.0	14.5	422	547	664	730	80	114	131	128
W K,	6.5	19.5	528	692	730	752	90	119	172	*151
S A,	2.5	18.0	396	572	740	795	71	117	151	154
A P (1),	4.0	19.5	481	579	802	853	62	113	219	233
A P (2),	6.0	23.0	562	696	821	884	59	108	218	256
A P (3),	5.0	21.0	364	502	804	912	40	96	197	216

It is remarked concerning Table III that the briquettes now (in first part of April) are about sixteen months old, and that it is surprising that all the sand briquettes made from foreign cement show signs of cracking, even those marked H, which, when twelve months old, appeared to be best. The signs of disintegration in the H briquettes are only visible at the corners, while the briquettes made from A P cement appear as yet to be all right. Mr. Lundteigen believes that the bad results with the foreign cements may be caused by the artesian water used, which contains in one liter:

1.0214 grams Ca SO_4.
0.2238 grams Mg SO_4.
0.1515 grams Na C_1.

It is to be noted that "more than 2030" in Table II means that the machine used could not break any higher, and that, therefore, the exact breaking strain could not be ascertained. In Table II the improvement in the cement D is very marked, while this is not so much the case with cement A P. The improvement caused by the "S" mixture is, as a rule, not very striking unless the concrete has had opportunity to harden for some length of time; the short normal test of one month is not decisive in this case.

Mr. Lundteigen says, finally, that according to his idea, one might, to advantage, make every high-limed Portland cement and mix same with the "S" material; cements mixed with this "S" material ought also to be good for use in sea-water.

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* These briquettes were badly cracked. Every number is an everage of three breakings.

A PORTABLE RECORDER FOR TESTS OF METALS.

By Gustavus Charles Henning, New York.

WHEN it is desired to know all about the working of a steam engine, to study the working of the steam valves, piston, clearances, etc., the indicator is used; this gives a record on rectangular co-ordinates of travel of the piston, and to the steam pressure throughout the complete cycle. Similarly, if it were possible to design an instrument like the indicator in its accuracy, portability, and universality, to record the behavior of materials from beginning to the end of the test, it ought to be of general utility for it, and its introduction ought to be comparatively easy. It should be complete in itself, readily and quickly applicable to all testing machines, and should be so constructed as to be readily examined for accuracy, and should, of course, be durable.

A great many recording instruments for stress-strain diagrams have been designed and used from time to time, but all have been found wanting in one or more respects, and not one has been made portable, so that engineers could take it from works to works, and use it without first being compelled to make more or less costly mechanical preparation for its use in each case. Moreover, the instruments in almost every case are so costly that their general introduction and use became impossible, especially in view of their limited utility. Some of them, otherwise very ingenious, gave diagrams on circular co-ordinates, which made them practically useless.

Among apparatus used for this purpose may be mentioned those of Wicksteed, Unwin, Kennedy, Barr, Gray, Martens, Olsen, Mohr, and Federhaff, and of Grafenstaden, but as they are fairly well known it is not necessary to describe them in this paper. My conception of a practical recorder for testing materials is as follows:

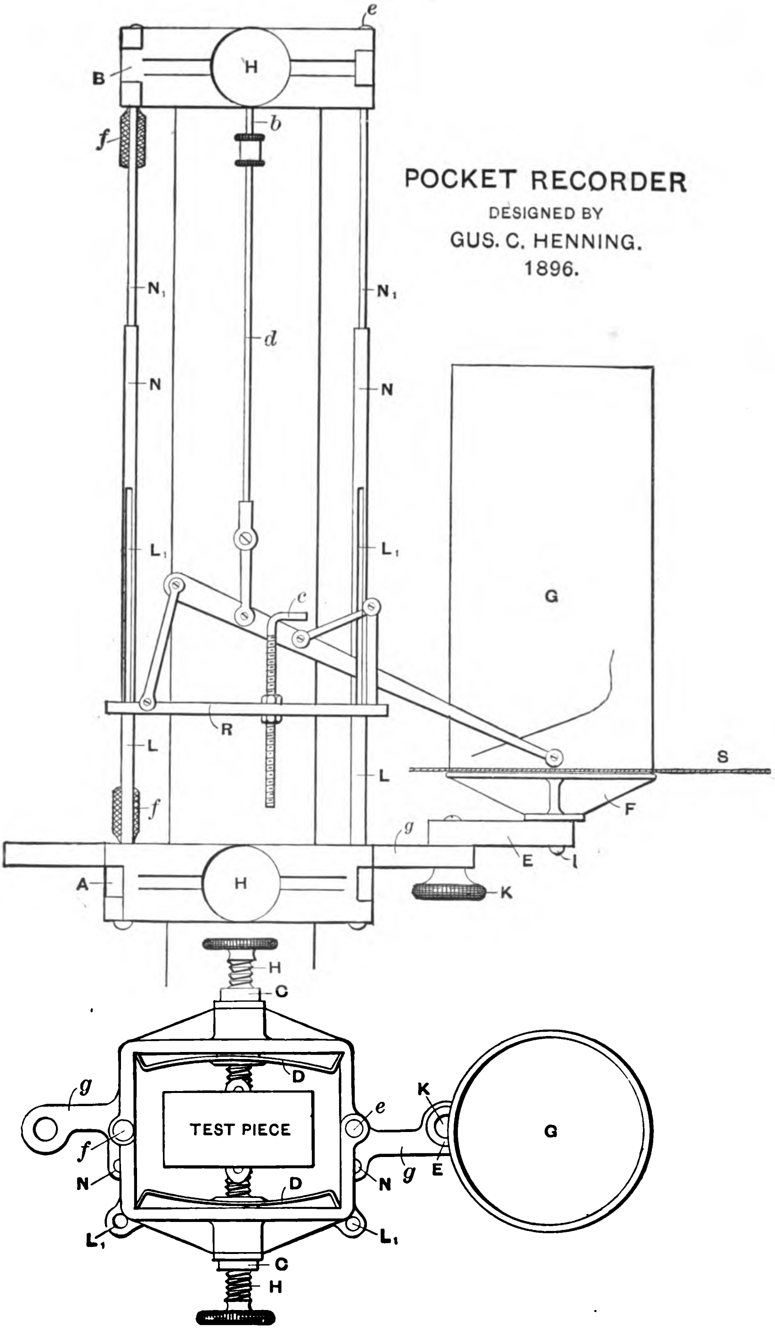
It must be portable and compact, requiring no extra precautions in adjustment or regulation, and, without having the accuracy of an instrument of precision, must be perfectly trustworthy, and as correct as the other apparatus in connection with which it is used. It must cover a wide range of work of short and long, large and small test-pieces, such as are found in general use, and must be applicable to hard and soft materials as well. The apparatus should be applicable in a horizontal as well as in a vertical position. Moreover, it should give a complete record from beginning to end of the test, showing the more important elements on an enlarged, and the lesser on a natural scale. Thus, while elongations within the elastic limit (yield point) are very minute, and must be recorded on a magnified scale which is trustworthy, changes of length beyond this critical point are very large, rapid, and variable; hence measurement with a steel scale suffices, and the record on a diagram may be on actual scale. This change of scale must, however, be positive, controllable, and at a fixed instant or point, and must not introduce errors in the record. In case of materials of slight extensibility, however, the entire record should be on one scale from beginning to end, and the instrument should be so attached that it does not nick or injure the material so as to affect its point of rupture or strength.

As materials under test change shape rapidly and constantly, the instrument must be so designed that this variation does not introduce errors by slipping, or tilting, or otherwise. Means must be readily applicable which will check the accuracy of the instrument at all times.

As materials are generally tested at the present time, there is no lasting record of the qualities that are claimed to have been found. Moreover, it is well known that many properties of materials cannot be determined except by an autographic stress-strain diagram. The curves obtained vary according to the treatment which the material has been subjected to, and annealing or straining produces such marked results that an autographic record would at once indicate how the material has been treated. Hardening, cold rolling, tempering, and other processes are made apparent by the characteristic features of the curves.

With the use of such a recorder it would become instantly apparent whether material had been previously intentionally strained to raise the elastic limit, as is well known to have been done. Overheating of material would be clearly indicated by the change in the curve, and the general uniformity of any lot of material could be readily determined.

The instrument should also be applicable for compression tests, so as to record the behavior of material when subjected to compressive stresses.



POCKET RECORDER
DESIGNED BY
GUS. C. HENNING.
1896.

Figs. 1, 2, and 3 show my designs of such portable recorder, as based on the conception as explained.

Figs. 1 and 2 are detailed sketches, while Fig. 3 is a view of the completed instrument. Two hinged frames F and F_1 are provided with knife-edged pointed screws S passing through bushes *b*, which carry springs E. Hinge pins *h* allow the frames to open, while taper plugs *p* secure them rigidly together when closed around the test-piece T.

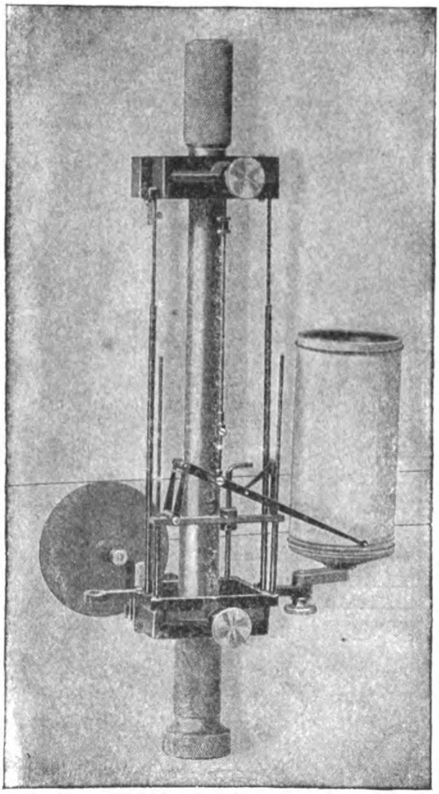


FIG. 3.

In order that the knife-edges K in the upper and lower frames bear on the test-piece T at given known distances, the guide rods g_1 sliding in tubes *g* are made of a certain length. These rods g_1 and tube *g* causes the frames F and F_1 to recede from or approach each other without changing their parallelism, and prevent any possibility of rocking of the lower frame F which carries the drum D on the arm A.

The drum D must remain at a uniform distance from the axis of the test-piece throughout the test, as any change therein would vitiate the record materially, either increasing or reducing the apparent length of string C.

The lower frame F also carries a parallel motion G L, as in ordinary use in steam engine indicators; this parallel motion is actuated by the upper frame F_1, through the connecting-rod N, which is interchangeable for longer or shorter pieces. The lever L of this mechanism carries a pencil or pen at *m*, which draws a line upon the paper wrapped on D, either horizontal when the drum is revolved, or a straight vertical line when the drum is stationary, and the frames F and F_1 approach or recede from each other. If the drum revolve while the lever L *m* moves, any curve may be obtained according to their relative motions. As the possible change of length of material during test, and up to the instant of rupture, is very great, a very long drum would be required to record it on a magnified scale up to that point; the parallel multiplying motion would also become very large and cumbersome. Moreover, the change of length within the yield point is minute, and cannot be recorded to any purpose except on a magnified scale. Now, therefore, to record the elastic changes of length on a magnified scale, and the permanent changes on a natural scale, as the latter are never measured closer than to the nearest $\frac{1}{100}$ in., I employ the following devices: The stop H arrests the multiplying mechanism at any desired point, after which it moves as a unit, and any further change of length is recorded on natural scale. To act as described, the parallel motion mounted on the bar G has two tubes R, sliding on rods R_1, the latter only being fastened to the frame F. These tubes R are split, and can be made to grip the rods R_1 with any necessary pressure.

It will be seen that the total maximum resistance to motion between frames F and F_1 is the friction of tubes *g* and R on rods g_1 and R_1, and friction of pen *m*. As long as the motion is recorded on a magnified scale this resistance will be only the friction of rods g_1 in tubes *g*, of pen *m*, and the resistance of the parallel motion.

Therefore the total resistance will be minute, and not likely to affect the record in even the slightest manner by slipping of the knife-edges and frames. The paper on the drum must move past the pen *m* at a rate equal or proportional to the motion of the poise weight on the beam. As loads are large and small according to size and quality of test-piece, the poise must travel more or less to balance it. As it is desirable, however, to record all tests on the same sized diagram, the travel of the poise weight is reduced or increased by a grooved pulley P, round any groove of which the string C tied to poise weight is wrapped; the free end of this string carries a small weight to keep it always at the same tension. On any other groove of the pulley P another string passing around the drum D is wrapped, which is kept at the same tension by a small weight at its free end. By a proper selection of position of the two strings on to various grooves of the pulley, any desired rotation of the drum may be obtained.

Application of Instrument.—A light pulley is secured to the frame of the testing machine, over which the string C passes, the other end being attached to the poise weight, or to any mechanism moving in synchronism with it.

Fig. 4.

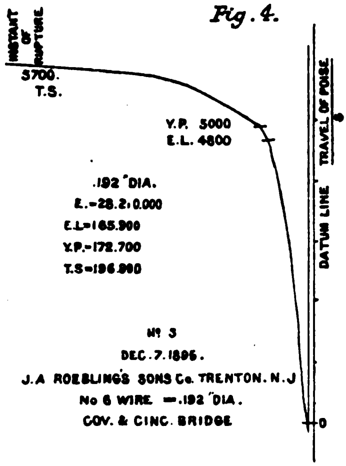


Fig. 5.

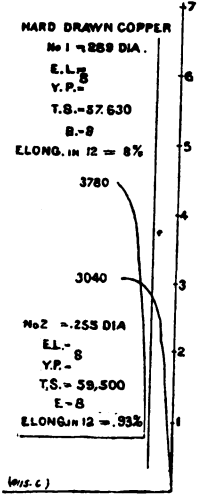
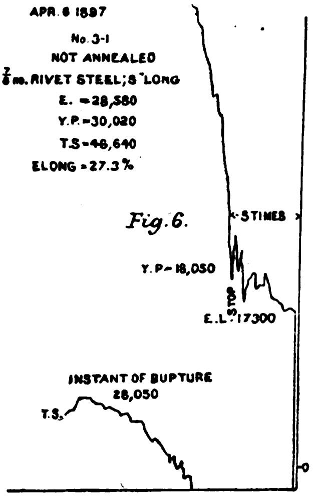


Fig. 6.



A sheet of paper being mounted on the drum, the frames F and F_1 are opened after the screws S have been so adjusted that the distances between the knife-edges K and K_1 are about $\frac{5}{8}$ in. less than the thickness of test-piece.

Then the frames are placed around the test-piece, which has been placed in the machine, the frames are closed, pins *p* are inserted, the string C_1 is passed around D, and C round the proper groove on P, while the poise weight is at 0 (zero), and the test may begin.

If it is desired to draw a base line for measurements of elongation, the drum is given one revolution while the pen bears against the paper; it is not necessary (though it can readily be done) to draw the other axis to the base line, as the motion of the pen is always at right angles to it. If it is desired to mark the scale of loads on the base line, all that is necessary is to revolve the drum by running out the poise to the several load points, and then making a mark for each of them. Once this scale is determined, it will be the same in all work.

In the case of materials with very slight change of length, during the test the automatic stop is not used, and curves like those on Figs. 4 and 5 are obtained. When ordinary structural material is tested, the stop is used, and a curve like that on Fig. 6 is obtained; in this, the elongation is drawn on a multiplied scale from o to the point marked "Stop;" beyond this it is drawn to natural scale. The very decided change of direction at the point marked "Stop" cannot be mistaken for anything else.

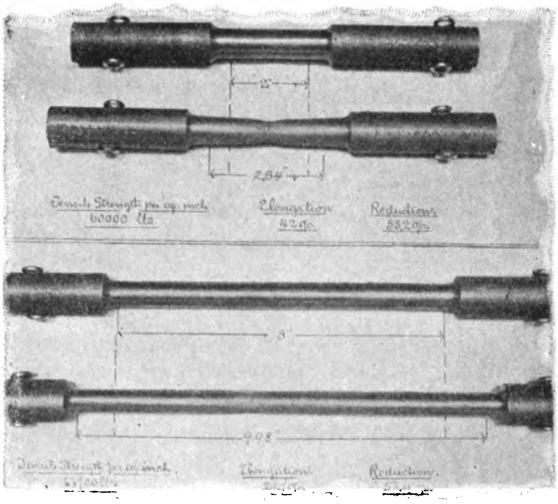
As all of the instruments hereafter made will have a multiplication of 10 times, this point of change of scale will be even more clearly defined than on the card shown.

An investigation of the effect of stretch of the string or wire has demonstrated that it is negligible, and the divisions marked on Fig. 2 will prove this. That it should be so will be clear when it is remembered that the drum revolves with a constant resistance, and that the string itself is always under constant tension, due to the small counterweight tied to the string C.

It will be noted that at the instant of rupture the apparatus can separate into two independent parts, and that the knife-edges permit a certain amount of slip; the combined effect of these two facts obviates any injury to the instrument at the instant of rupture, provided the accidental flying about of the gripping wedges is prevented by blocking them, which is always done by a careful person.

Experience has shown that the instrument can be used rapidly without interfering to any degree with the work of the laboratory, and that the results are perfectly trustworthy.

A VERY neat and satisfactory way of showing up test-pieces and their performance is that displayed in the engraving herewith, which is reproduced from a small 3½x4½ in. photograph. It will be seen that the original test-piece is suitably hung up, and that its mate, after having left the machine, is hung up immediately beneath it. The lines and figures as shown are then drawn, and we have a graphical presentation of the amount of elongation given in a most striking manner. The whole is then photographed, the print being mounted on a small pocket size card, and an interesting story of the quality of the metal is thus provided in a very handy form. It will be noticed, by the way, that the material shown in this photograph is pretty good. The test-pieces are from open hearth steel castings made by the Sargent Company, of Chicago. The upper piece shows a tensile strength of 60,000 lbs., an elongation of 42 per cent., and a reduction of 53 2 per cent. The lower piece shows a tensile strength of 63,700 lbs., an elongation of 24.7 per cent., and a reduction of 53.9 per cent.—*Railway Master Mechanic.*



THE POLARIZING PHOTO-CHRONOGRAPH.

THIS new physical laboratory apparatus* for measuring exceedingly short intervals of time was developed by Prof. A. C. Crehore, of Dartmouth College, and Lieutenant George O. Squier, Instructor at the United States Artillery School, Fort Monroe, Va.

The principle upon which this instrument is based is the discovery by Faraday that a magnetic field will rotate the plane of polarization of light, and the advantage of applying this principle lies in the fact that thereby a camera shutter ***without mass*** is practically obtained.

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* Constructed by Mr. J. A. Brashear, Allegheny, Pa.

The plate shows the general arrangement of the parts of the instrument. On the inverted T-rail O′ are placed an arc lamp *a*, a condensing lens L, the polarizer (a Nicol prism) P, the coil T (inclosing a tube filled with carbon bisulphide), the analyzer A (another Nicol prism), and the lens L′. On the inverted T-rail O are placed a mirror M (which reflects the light from the arc lamp), a condensing lens L″, the tuning-fork F (which has a little piece of aluminium foil, perforated by a small hole, attached to one prong), and the magnifying lens L‴. The T-rails travel on two rails VV′ in such a way that each may be moved independently of the other by means of the screws S S.

The receiver is a sensitized glass plate revolving in its plate holder, which is mounted in a heavy cast-iron fly-wheel W, rotated by a small motor *m*. The light for the chronograph record is made to pass through a narrow radial slit in the plate holder; that from the tuning-fork reaches the plate through a round opening.

At U is represented the *gravity switch*, which consists of a weight falling so as to make two contacts in succession, first, one which causes the material shutter of the camera to drop and expose the plate, then (an instant later) one which starts the motion which we desire to measure.

The operation of conducting an experiment is as follows:

The lamp current is started; the polarizer and analyzer are set so as to produce darkness at the focus of the lens L′; a current is sent through the coil of the tube T, and in the passage of the beam of light through the carbon bisulphide (which is in a magnetic field so long as the current passes through the coil) its plane of polarization is rotated through a certain angle, and light emerges from the analyzer; the motor is then made to rotate the plate; the fork is set vibrating; and the weight on the gravity switch is dropped.

The material shutter of the camera drops and the plate is exposed at the radial slit and the round opening. The moving body, the velocity of which we are measuring (a projectile fired from a gun, for example), is made to break the circuit at a series of screens arranged in succession in its path, contact being made automatically after each break. Now, whenever the current is broken the carbon bisulphide, being no longer in a magnetic field, loses its rotary power, and hence there is darkness, or a break in the chronograph record, in other words, our massless shutter has fallen and shut out the light; as soon as the circuit is closed again our massless shutter is opened and the light let in, and so on. The tuning-fork record of the light through the aluminium foil on the fork is continuous, and since the number of vibrations of the tuning-fork per second is known, this record could serve to measure the intervals of time between breaks, by merely counting the vibrations recorded on the plate in the tuning-fork record.

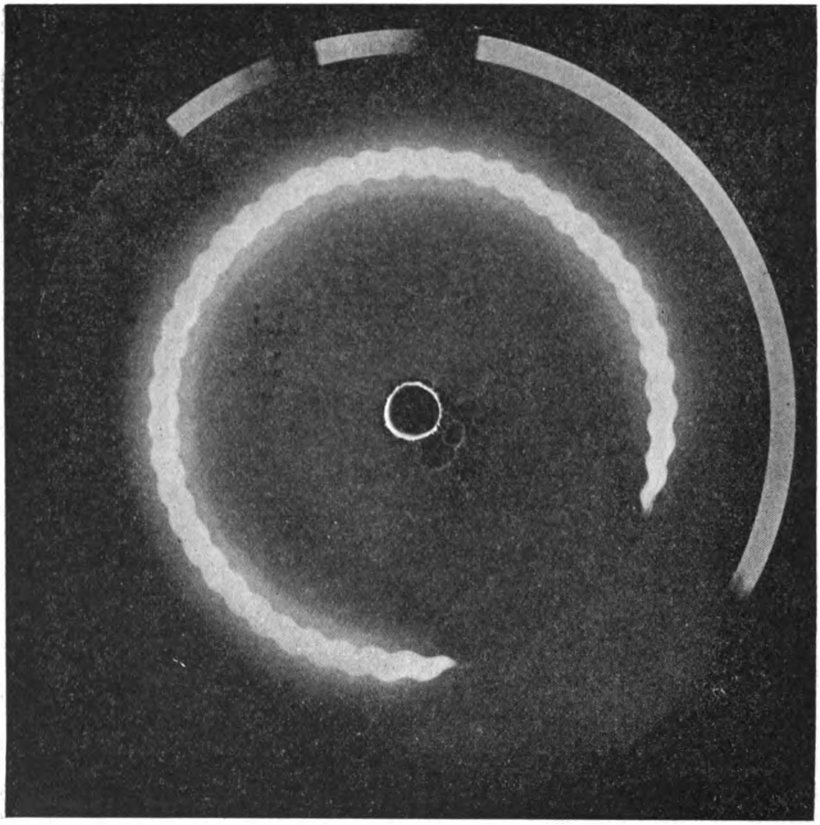

FIG. 3.

The inner is the fork record; the outer is the chronograph record (3 breaks) for the projectile, *exterior* velocity.

But for simplicity, as well as greater accuracy, the number of vibrations of the fork (waves on the plate) in the total fork record is noted, and the *angle* made by radial lines through the extremities of this record is measured; then, by also measuring the *angles* subtended by the arcs between two successive breaks in the chronograph record, the corresponding times may be readily determined, since the rate of vibration of the fork is known.

To do this easily and accurately a measuring instrument * (shown in the illustration) is provided, which is furnished with arrangements for accurately centering the glass negative, and with micrometer microscopes for accurately reading the angles.

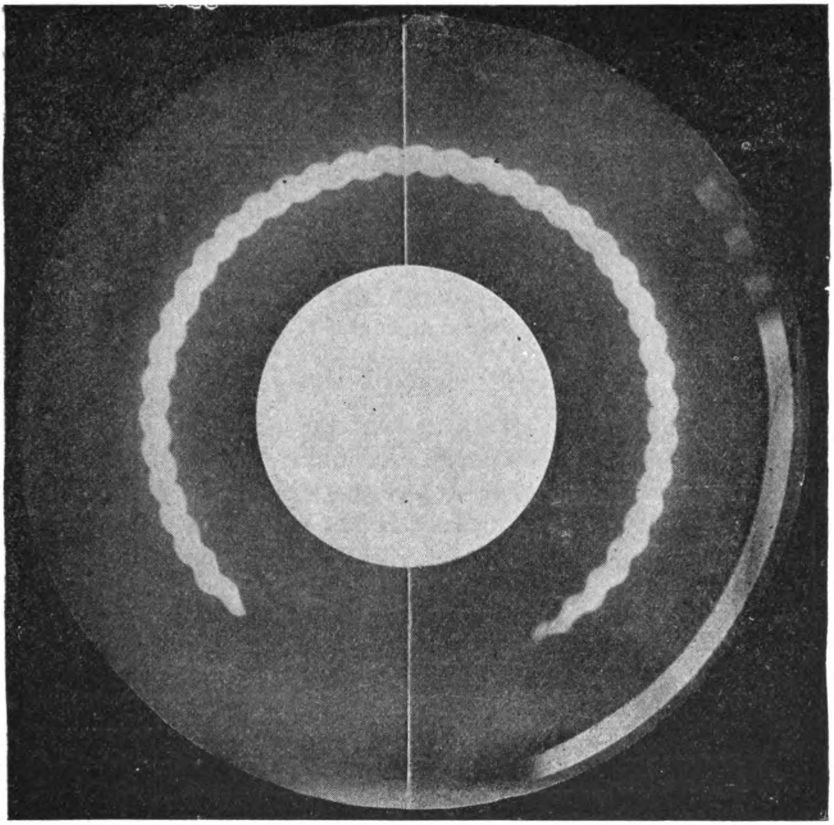

FIG. 4.

The inner is the fork record; the outer is the chronograph record (4 breaks) for the projectile, *interior* velocity.

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* Constructed by Messrs. Warner & Swasey, Cleveland, Ohio.

The practical value of the chronograph is evident from the fact that by means of it the velocity of a projectile has been measured at seven consecutive points inside the bore of a field gun, and the instantaneous values of an alternating current which is changing its direction hundreds of times a second have been determined.

For a full description of this valuable piece of apparatus, which opens such a wide field of physical investigation, the reader is referred to the book on the subject recently published by John Wiley & Sons, New York.

TESTS OF HYDRAULIC MATERIALS.

By H. Le Chatelier, Professor at the Ecole des Mines, Paris, France.

From "Transactions"—American Institute of Mining Engineers. Chicago meeting, being part of the International Engineering Congress, August, 1893.

[Translated by the Secretary.]

HARDENING OF HYDRAULIC MATERIALS.—The property of hardening in contact with water, which characterizes hydraulic materials, belongs to a large number of different chemical compounds, some of which can be studied more easily than limes or cements. The sulphate of soda, previously fused and finely pulverized, sets rapidly when tempered with a little water, behaving like plaster, only still more quickly, by reason of its greater solubility. The mechanism of this setting is easy to trace.* The anhydrous salt dissolves in contact with the water, the concentration increases rapidly, passes the point of saturation for the salt with ten molecules of water, and tends to reach that of the anhydrous salt. But such a solution is not stable in contact with the small quantities of hydrated salt which form on the surface of anhydrous salt exposed for a certain time to air. The supersaturated solution in process of formation soon commences to crystallize, giving the salt with $10H_2O$. Meanwhile, the anhydrous salt not in the presence of its completely saturated solution goes on dissolving. These two inverse phenomena of crystallization and solution take place each at its own rate of speed,

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* H. Le Chatelier, "Recherches experimentales sur la constitution des mortiers hydrauliques."—*Annales des Mines*, Mai-Juin, 1887, p. 20.

whence there results for the liquid a certain state of mean supersaturation, which does not completely disappear until there is no longer any anhydrous salt remaining to be hydrated. The final set is thus the result of a transitory solution, rendered possible by the difference in solubility of the different states of the salt. In the case of sulphate of sodium, by reason of its great solubility, this transitory solution can be very clearly proved. It is sufficient, instead of taking the salt as fine powder, to break it into fragments of pea size, and place these in the upper part of a vase filled with a saturated solution of hydrated salt. The supersaturated solution which forms is able to flow down through the larger interstices between the fragments and to fall to the bottom of the vase, where the $10H_2O$ salt crystallizes out in a compact mass. The transfer of the salt corresponding to its hardening is the certain proof of a transitory solution.

With less soluble salts, like the sulphate of calcium, the phenomena are the same, though less easy to observe. Calcined plaster gives with water a supersaturated solution containing 10 grammes of sulphate per liter (1 per cent.), as against 2.36 grammes (0.24 per cent.) in the saturated solution of the hydrate.

The aluminates of calcium occurring in cements, although scarcely soluble when once hydrated, give, when anhydrous, in contact with water, solutions of relatively high supersaturation. By agitating pulverized aluminates of calcium for five minutes with an excess of water, 0.5 gramme of this salt may be dissolved per liter (0.05 per cent.); but it soon precipitates hydrated crystals, and finally there is no measurable quantity of aluminate left in the liquid.

The same process should take place with the silicate of calcium, which is the essential hydraulic element in all limes and cements. But the solubility of this salt is so low, and the determination of small amounts of silica is so delicate a matter, that it has not yet been possible to demonstrate experimentally the supersaturation of water with the anhydrous silicate. This has, however, been done for an analogous salt, the silicate of barium, which is somewhat more soluble, and which likewise sets in contact with water.

The hardening of hydraulic materials thus seems to be in all cases the result of the crystallization of hydrated compounds which have passed through a momentary state of solution. But the solidity of such a crystalline mass may vary within considerable limits according to the form, dimensions, and mode of segregation of the crystals thus produced. In general the cohesion or hardness of an isolated crystal is much greater than its adherence to adjacent crystals. The more the crystal-surfaces in contact are developed, the greater the total adherence and the strength of the mass. Crystals in long plates or in interlocked fibres should give a considerable strength. Now it happens precisely that all crystals deposited from supersaturated solutions present these characters, and do so in more marked degree the higher the degree of supersaturation of the mother solution. The crystallization of supersaturated solutions of sulphate, acetate or hyposulphite of sodium gives filiform crystals several centimeters long and less than 0.1 mm. (0.004 in.) in diameter. The same may be recognized in the setting of plaster, aluminates of calcium, etc. But this elongation, and the resultant solidity, may vary to a considerable extent with the degree of supersaturation, and this in turn depends upon multiple conditions—the fineness of the anhydrous salt, the number of centres of crystallization, etc. It is for this reason that hydraulic products very nearly alike often give in use, whether in actual construction or under experimental tests of strength, results so different.

SWELLING BY SLACKING.—In most cases the action of water on anhydrous salts is a cause of hardening; but this is not always so. We know that lime, in becoming hydrated, cracks, disintegrates; in a word, is slaked or "slacks." In order that a hardening shall take place, the anhydrous salt must be able to subsist for a certain period in contact with water simply dissolving the latter, but not combining with it. This is impossible for certain substances which have a strong affinity for water, such as lime, baryta, boric acid—anhydrides which combine directly with water, forming hydrates prior to any solution. In these cases, which are very few, there is a disintegration of the substance and a simultaneous swelling with enormous force. For instance, it is well known that a fragment of quicklime enclosed in a brick may, in slacking, burst the brick.

Substances which set in contact with liquid water may swell when hydrated in contact with the vapor of water. This is the case with sulphate of sodium, plaster, and aluminate of calcium. But in this case the hydration is often extremely slow, and may even go no further than the exterior surface. This phenomenon of swelling is one of the most active causes of the disintegration of cements; and its examination should be one of the most important objects of the methods of testing.

CHEMICAL COMPOUNDS IN CEMENTS.—The compounds usually encountered in cements and hydraulic limes are lime and its combinations with silica, alumina, oxide of iron and sulphuric acid.

LIME.—Anhydrous lime always slacks—that is, disintegrates and swells during hydration.

The time required for slaking lime varies greatly with its degree of compactness. The porous lime obtained by burning pure limestone at low temperature slacks instantly in contact with water, while the compact lime produced by calcining nitrate, or, at high temperature, somewhat argillaceous carbonate of calcium, takes several days.

Slacking is more rapid and swelling greater the higher the temperature. This is a fact of capital importance, which is utilized in the treatment of hydraulic limes not conveniently slacked when cold, and also in the testing of cement to detect the presence of free lime.

Swelling is greater from vapor of water than from liquid water.

Finally, slacking is considerably hastened by the addition to the water of a small quantity (two to six per cent.) of calcium chloride, or of salts like magnesium chloride, which yield with the lime of the cement chloride of calcium. Thus, a lime which takes forty-eight hours to slack in pure water does so in half an hour if ground with a three per cent. solution of calcium chloride. These facts, discovered by M. Candlot,* have received several interesting applications.

The presence in hydraulic limes and cements of anhydrous lime free—that is to say, not combined with acids or water—is, as has been observed above, one of the most important causes of the destruction of these products. When the slacking of the lime is so slow as not to be accomplished until after the setting, it causes by its swelling, if it is in notable quantity, cracks in the whole mass and a consequent disintegration of the mortar. If it is present in small quantity, it produces an increased porosity, facilitating the destructive action of exterior agents. The addition to a good Portland cement of one per cent. of compact lime (from nitrate) is enough to cause distinct cracking.

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* Role du chlorure de calcium et du sulfate de chaux sur la prise et le durcissement des mortiers.—*Bulletin de la Société d'Encouragement pour l'Industrie nationale.* Juillet, 1890. Paris. Siege de la Societe, 44 Rue de Rennes.

Free magnesia gives rise to analogous but less important swelling.

SILICATES OF CALCIUM.—There are three silicates of calcium, viz.: (1) CaO, SiO_2, or wollastonite; this does not occur normally in cements. It is produced only against the walls of the furnace and at the expense of their silica, especially when the lining, as in some works, is made of sandstone. It possesses no hydraulic property, and is an inert material. (2) $2CaO, SiO_2$; this silicate has the singular property of spontaneous decrepitation to powder upon cooling, a consequence of allotropic change of condition. The phenomenon resembles that which is produced under the same conditions of cooling with oxide of lead, sulphate of potassium, and especially with the double sulphate of copper and potassium. This spontaneous crumbling of the dicalcic silicate, very frequent in basic blast-furnace slags, also occurs frequently in Portland cements. It is the more marked the weaker the proportion of lime and the higher the temperature of burning. This silicate possesses no hydraulic properties. It does not harden in contact with water. But it is rapidly attacked by dissolved carbonic acid, with the formation of crystalline carbonate of calcium, and it may thus contribute in some degree to the final hardening of mortars. (3) $3CaO, SiO_2$; this is the only really hydraulic silicate; it is *par excellence* the active element of hydraulic limes and cements. In Portland cement, of which it constitutes the greater part, it occurs in pseudo-cubic crystals. It is produced by the reaction of silica and lime in the presence of fusible combinations formed by iron and alumina. When overheated, it appears to be decomposed into dicalcic silicate and free lime, thus losing its hydraulic properties. In contact with water it sets, dividing so as to give hydrated monocalcic silicate crystallizing in microscopic needles and calcium hydrate crystallizing in large hexagonal plates which are visible to the naked eye in all Portland cements.

$$3CaO, SiO_2 + Aq = CaO, SiO, SiO_2$$
$$2, 5H_2O + 2(CaO, H_2O).$$

The hydrated silicate in the presence of an excess of distilled water decomposes until the moment when the solution contains 0.052 gramme of CaO per liter.

The supersaturation which precedes crystallization is difficult to recognize for the monocalcic silicate. It is very clearly proved, on the other hand, for the simultaneously formed hydrate of lime.

This silicate is but slightly sensitive to the action of water vapor. This enables it to pass unharmed through the period of slacking in the manufacture of hydraulic limes. It is upon the proportion of this silicate that the quality of a hydraulic product principally depends.

ALUMINATES OF CALCIUM.—There exist different aluminates of calcium, all of which set very rapidly in contact with water. The most important, tricalcic aluminate, is simply hydrated in contact with water like plaster, producing highly supersaturated solutions.

$$3CaO, Al_2O_3 + Aq = 3CaO, Al_2O_3, 12H_2O.$$

This relatively unstable hydrate loses its water and efflorescence in warm and dry atmospheres; it may thus become a cause of destruction in mortars used in air. In contact with distilled water it decomposes until the solution contains 0.22 gramme of CaO per liter. This salt, according to the researches of M. Candlot, combines with sulphate of calcium to form a double salt which crystallizes with a very large quantity of water.*

$$3CaO, Al_2O_3, 2.5(CaO, SO_3), 60H_2O.$$

This compound appears to play an important *rôle* in the destruction of mortars in sea-water. It is formed at the expense of the sulphuric acid in the sulphate of magnesium. This is a point of capital importance which deserves to be studied more completely, and which will some day undoubtedly be utilized in the testing of cements destined for marine works.

The existence of hydrated aluminates containing less than three molecules of water has not yet been established; but that an aluminate of the composition, CaO, Al_2O_3, Aq, exists may be regarded as highly probable. Such a compound cannot, however, be formed under normal conditions in cements which always contain an excess of lime.

Calcium chloride combines with the intermediate aluminate, $2CaO, Al_2O_3$, but the combination is destroyed in the presence of an excess of lime, the tricalcic aluminate being formed in its stead. When cements are tempered with sea-water, the combination with calcium chloride occurs during the setting, which it retards, but it disappears as soon as the hydration of the calcium silicate has liberated sufficient lime.

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* Candlot.—*Loc. cit.* (*Bulletin de la Société d'Encouragement*) and Candlot's *Ciments et Chaux*, No. 250, Librairie Baudry (1891).

FERRITES OF CALCIUM.—These compounds swell like free lime under the first action of water, and then give birth to a white hydrated tricalcic ferrite, which latter is decomposed by the carbonic acid of the air with the production of brown sesquioxide of iron. These compounds do not exist in well-burned Portland cements, which never assume in the air the characteristic burned color mentioned.

SILICO-ALUMINO FERRITES OF CALCIUM.—There is produced in the Portland cements a fusible silico-aluminate identical with that which forms the essential element of crystalline blast-furnace slag, in which the sesquioxide of iron partially replaces the alumina.

$$3CaO, Al_2O_3, 2SiO_2.$$

This substance is completely inert under the action of water; it does not appear even to be attacked in the long run by carbonic acid. Its only useful function is to serve as a flux to favor during the burning the combination of silica and lime.

This silico-aluminate crystallizes in Portland cement by reason of the slow cooling, but may, on the other hand, retain a vitreous texture when cooled with sufficient suddenness. This is the case, for instance, when blast-furnace slags are precipitated while still liquid into cold water. The properties of this compound then become entirely different. It is attackable by weak acids, and at the same time by alkalies. It combines particularly with hydrated lime in setting, and giving rise to silicates and aluminates of lime identical with those which are formed by entirely different reactions during the setting of Portland cement. It is upon this property that the manufacture of slag-cements, which assumes daily greater importance, is based.*

WE take pleasure in referring our readers to an excellent list of Portland Cement References, 1892–1896, compiled by Professor Thomas B. Stillman, Ph. D., which appears in the October, 1896, number of the *Stevens Indicator*, Volume XIII, No. 4, folio 443 to 446, continued from Volume X, 1893.

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* Prost.—Note sur la fabrication et les propriétés des ciments de laitiers.—*Annales des Mines*, 8e serie, tome xvi, pp. 158 to 208.

STEEL AND IRON AXLES.*

By R. A. Mould.

THE period we have just passed through might be properly termed the "Iron Age," and should I ask you which metal—steel or iron—you would prefer for axles, the majority would answer, "Iron." Why? Because many have become gray in the manipulation of the same, and stand ready to produce the strongest evidence from their years of experience and practical work, from the scrap pile, fagot, and finished axle, showing that this metal produces the strongest and best axles to withstand the strains and stresses to which they are subjected, under the heavy loads and high rate of speed of this progressive age.

Our cars have increased—almost doubled—their former capacity, and our locomotives, with the high pressure of steam, make it necessary that an axle be made of the best material possible, in order to meet the requirements of to-day. Iron has been the only material we have had with which to make axles strong enough to withstand the strains to which axles are subjected, through the high speed, high pressure, and increased tonnage of this the "Age of Progress."

A necessity for something better, without too large an increase in weight, was fully realized, and wonderful developments have been made in material for axles, and, in fact, for all portions of car and locomotive forgings. For axles, we have the low-carbon steel made by the Bessemer and open-hearth processes, and we find ourselves in what might be called the "Steel Age." I believe it has come to stay, as our scrap piles have now become unfit to produce good iron axles, owing to the impurities which they contain; at least, that is our experience in the Eastern market. The demand for better material and the spirit of competition soon made steel a strong competitor against iron in the markets of the world as the proper and best material for axle making:

First—Because of its being more homogeneous than iron.

Second—Because of its being free from seams and soon forming a better bearing than iron.

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*A paper by the President of the National Railway Master Blacksmiths' Association, read at the fifth annual convention at Chicago, September 8th, 1897.

Third—Greater loads can be borne by steel than by iron axles of the same dimensions.

It was said by one of our members, while this subject was under discussion at the last convention, that the Bessemer process of making low-carbon steel was not reliable for axle making, and, upon investigation, I find that many of the failed steel axles have been made by this process. Upon the Erie system, upon which I am employed, we have been using open-hearth low-carbon steel for crank pins, side and main rods, piston rods, locomotive driving axles, engine truck, tender truck, passenger and freight car axles, with the most satisfactory results, for a number of years.

Mr. Goodell, our mechanical engineer, has kindly given the records of failures of all classes of axles upon our system, from all causes, and our reports show that 57 iron axles and only 14 steel axles have failed. During the last two years and four months the average rate of failure has been 14 iron and three steel axles per year; the failure of steel axles forming but 18 per cent. of the total number of failures. The reports upon which these statistics are based cover axles of all classes, freight and passenger cars, engine truck, engine tender, and driving axles.

Almost all the outside bearing axles which have failed have fractured in the journal, the most common cause of failure being seamy and dirty iron, fillets worn sharp, and improper or deficient lubrication, causing journals to run hot. We have generally been able to trace the failure of nearly all of the steel driving axles which have failed to some surface defect, such as circumferential scoring, due to careless lathe work, or cutting due to wear. The sections of driving axles at which fracture takes place is about in the plane of the inner face of the driving-wheel hub. It is very rarely the case that we receive a specimen which indicates a clean break throughout. At the time of ultimate failure nearly all specimens show that fracture has occurred more or less gradually. We frequently receive broken iron journals, the fractures of which indicate that they have been very hot and that the outside fibres have been severed, and that just previous to ultimate failure the journal was kept in shape by a central core of fibres, all of which gave way simultaneously.

In general steel axles are superior to iron axles in homogeneity, in ability to resist abrasion and in ability to resist greater stresses, both quiescent and repeated alternating stresses. Iron axles are made of scrap of good or bad quality, according to the nature of the scrap selected for their composition. To be perfectly sure that iron axles are of the quality specified it is necessary to test each axle in some way or other, for iron is far from being homogeneous. Moreover, in iron axles, there is always some danger of the existence of steel scrap, which never thoroughly unites with the adjacent iron and therefore is a source of weakness and danger.

Steel axles are usually made of new material, and the mass of steel worked at one time, and from which either Bessemer or open-hearth axles are made, is often sufficient to produce from 50 to 75 axles. As this steel is very homogeneous the axles have a physical and chemical composition almost exactly alike, the principal cause of difference being segregation or a separation of certain elementary substances in the steel, such as sulphur, phosphorus, and manganese. Segregation, however, rarely becomes a defect of axles because most steel axle manufacturers discard a certain portion of the top of the ingot, in which portion of the ingot almost all the segregation takes place, and the portions of the ingots used for the manufacture of axles are, generally speaking, free from this defect. Not only are axles of the same heat or run of metal quite homogeneous, but most metals of various heats are so nearly alike that the difference between physical and chemical properties of axles made of various heats are very slight. If it is especially desired that axles shall be exactly alike in physical and chemical composition, axles of certain heats may be especially selected with this in view, the selection of the heats to be used depending upon a careful consideration of the chemical and physical properties of the metal as shown by the manufacturers' tests.

A thorough competitive test of the wearing qualities of iron and steel taken from axles has recently been made by the Cambria Iron Company on a machine specially designed by Riehlé Bros. Testing Machine Company of Philadelphia. In these tests the specimens taken from the different axles were so formed as to present the same extent of wearing surface. Small cubical sections of metal were cut from the journals of the axles as near the surface as the shape of the section would permit, and the faces of these cubes were planed and polished in order to place them in as nearly the same condition as possible. The cubes were then placed upon a steel disc which had been prepared and they were pressed against the disc with a constant pressure, and the disc was made to revolve.

Eight specimens from wrought iron and 17 from steel axles were thus tested. The average loss of weight by wear per unit of surface presented, during 200,000 revolutions, was as 21.26:12.4, for the iron and steel respectively. Seven grades of iron and steel were used in this test, and they withstood abrasion in the following order, the first mentioned suffering the least loss and the last mentioned suffering the greatest loss:

Open-hearth toughened by Coffin process, steel.
Open-hearth, untreated, steel.
Bessemer toughened by Coffin process, steel.
Bessemer, untreated, steel.
Muck, bar-mill scrap, iron.
Western scrap-iron axles.
Eastern scrap-iron axles.

In order to withstand repeated and alternating stresses for an indefinite length of time, the greatest stresses should be quite a little less than the elastic limit of the material of which the piece so treated is composed. It is customary to so design axles as to make the greatest intensity of stress one-third the ultimate strength of the material; as the ultimate strength and elastic limit of steel are greater than similar properties of iron, it follows that greater loads can be safely borne by steel axles than by iron axles of the same dimensions. With mild steel having a tensile strength of 60,000 lbs. per square inch, and iron having a tensile strength of 50,000 lbs. per square inch, the greatest stresses which axles composed of these materials could withstand without becoming fatigued would be about 20,000 lbs. per square inch and 17,000 lbs. per square inch, respectively.

POINTS IN TIMBER TESTING.

EDITOR DIGEST OF PHYSICAL TESTS.

SIR:—The comprehensive series of timber tests undertaken by the Division of Forestry—which, by the way, have not so much in view the establishment of strength values as to furnish data of inspection—have developed two points of highest interest to the science of timber testing. The one is with reference to the influence of moisture on strength, the other with regard to the use of small or large sizes in testing.

That the decrease of moisture, due to seasoning of timber, increases its strength, and hence that tests must be made and strength values used with due reference to the moisture per cent., was long ago demonstrated by Bauschinger, but I believe it was not known hitherto that there is no such influence of the moisture per cent. above a certain limit, this limit being somewhere near and above 32 or 33 per cent. In other words, the loss of water in green timber, which may contain as much as 100 and more per cent. of its dry weight of water, does not produce any change in the strength until the above-named limit is reached: the upper portion of the curve, which expresses the relation of moisture and strength, is a straight line. That this should be so is not surprising when we realize that the water contents of the wood may be found in the cell wall and in the cell lumen.

When a piece of wood takes up water this will first be absorbed by the cell walls producing a swelling of the same, and when the walls have absorbed all they can, then the lumen will fill; *vice versa*, in seasoning the lumen is first emptied—through the cell wall, of course—the water in the lumen following into the wall as the water of the latter is evaporating. When the lumen is exhausted the wall gives up its water, and in consequence shrinks. As a result, more solid material is found in a cubic foot of the drier or dry wood than there was in the swollen condition of the material, and hence the strength increases. It appears that the loss of water from the wall of the wood of the Southern pines begins at about the limit indicated. To be sure, heartwood rarely contains water in the cell lumen.

The practical deduction seems to indicate that for the determination of standard values of strength the timber should be tested when green or saturated, for then the varying moisture contents do not influence the result, and in addition we get the lowest absolute values. Thereby we obviate the difficulty—almost impossibility—of determining the moisture per cent., which in its lower values influences to such remarkable extent as has been shown by the test result. We may then work out independently and carefully a curve of correction for the drier conditions, or else determine otherwise reasonable factors of safety.

The other point of significance, which, if not established, is at least indicated by our tests, is that for cross-bending strength at least the size of the test-piece (within limits) does not influence the result, as has been thought; in other words, the suspicion of engineers that the data obtained from the usual laboratory tests are not applicable to large sizes used in practice, *ceteris paribus*, seems to lack foundation. Beams of eight to twelve feet in length and eight to sixteen inches square have developed as much and greater strength than the small sizes cut from them.

The explanation of this fact—if on further careful inquiry it remains a fact—is not as simple as in the case of the moisture influence. A suggestive indication of the cause, however, may be found in the observation that really straight-grained wood seems the exception rather than the rule; in the large beams a larger number of entire fibres are tested, while in the smaller pieces more fibres are probably cut obliquely, ending in the longitudinal planes, and hence are unable to develop their full strength.

In columns or compression pieces, where the entire cross-section is under stress, the defects are naturally of more moment than in beams where only the extreme fibres come into play. Here, therefore, the large column, which is almost certain to contain more defects, is apt to develop lower values, yet it is not size but quality of the material that exercises the influence.

For the purpose of establishing lowest standard values, then, tests on green material of small size would appear most desirable, with such additional data for variations in moisture and other conditions as will allow an estimate of their influence.

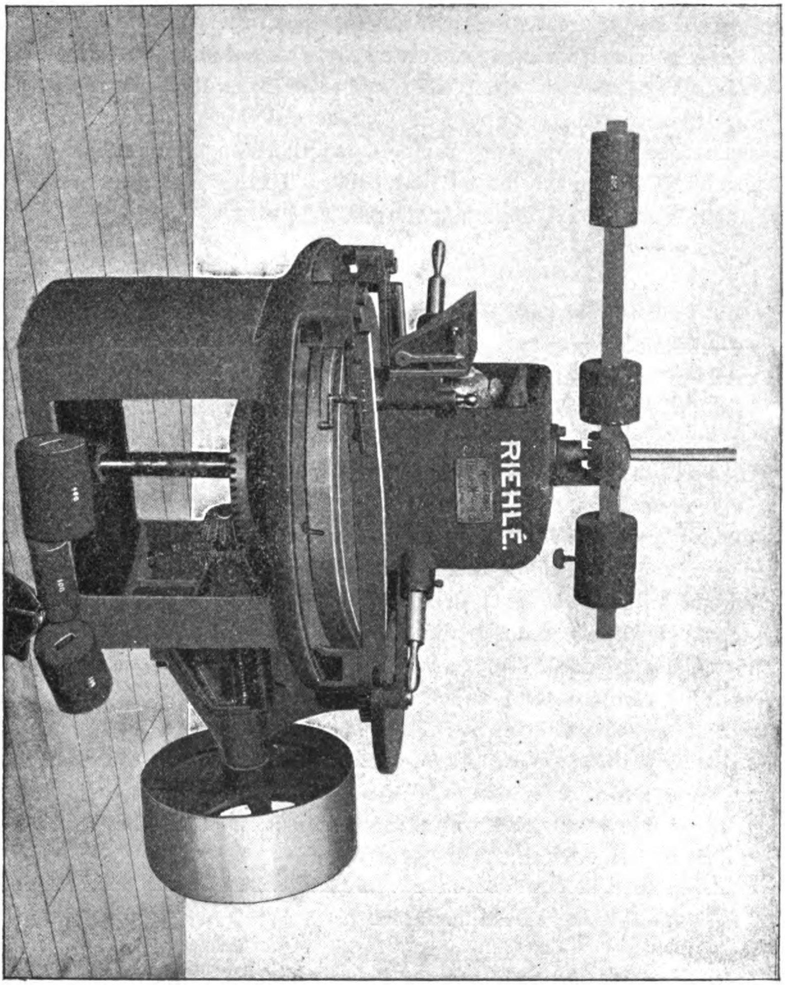
It is hoped that these interesting indications, developed in a series of tests which had not been intended for this demonstration, may be worked out with carefully devised tests designed for the purpose to their full conclusions. Yours truly,

B. E. FERNOW,

Chief U. S. Dept. of Agriculture, Div. of Forestry,
Washington, D. C.

ABRASION TESTING MACHINE.

THE machine illustrated on opposite page is especially designed for the modern requirements of testing by abrasion. The capacity of machine is from a 12-inch cube down to a 3-inch cube of any material. The load for abrasion may be varied from 10 to 1,000 pounds. The abrasion is done by a disc of steel having a rotary motion and a weighted box, holding specimen, reciprocating across each side of centre of disc; sand and water may be applied through hopper, in which a graduated valve regulates the supply. A revolution counter is also provided. The whole apparatus forms a



ABRASION TESTING MACHINE.

very necessary equipment for engineers in charge of works, dealing with stone, brick, metals, etc., where resistance to abrasion forms so important a factor. Its usefulness has been fully appreciated by the Cambria Iron Co., for they were enabled to make very exhaustive tests on the wearing qualities of *iron and steel, which practically proved the great superiority of steel to iron in resisting abrasion. It is easy to see how readily such a machine can determine the oft-perplexing question, whether this or that brick is best suited for paving, thus relieving the engineer from considerable worry, and at the same time providing very useful data otherwise unobtainable. The machine is manufactured by Riehlé Bros. Testing Machine Co., 1424 North Ninth Street, Philadelphia, Pa.

TESTING METALS BY SOUND.—"Chiseophone" is the name of an instrument invented by M. L. de Place for ascertaining the existence of internal defects in iron articles, especially rails, rolled joists, and axles, that cannot be detected by other means. A percussive needle, with reciprocating motion, is connected with a microphone in the form of a ring, in the circuit of which is a battery of three dry cells, coupled in series, of very slight internal resistance, with an induction coil, the latter being fixed at the zero of a divided scale on which may travel a movable coil, while two telephones, which the examiner holds to his ears, are intercalated in the circuit. When the needle strikes a portion of the material free from faults, the telephones give back a very distinct sound, which becomes slighter when the coils are further apart; and, if the needle strikes a place where there is a defect, the sound is modified in proportion to the cavity. Owing to the modification of the resonance, the microphone undergoes a modification of resistance, and the previous equilibrium is upset, so that the telephones give out a sound which indicates the position of a defect in the metal.

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* See article on Steel and Iron Axles.

PROFESSIONAL NOTES.

ERRONEOUS USE OF EULER'S FORMULA.

The formula which Professor Barr uses for piston rods, $P = \frac{\pi^2 E I}{4 L^2}$, is not Euler's formula for any kind of end conditions. The three forms of this formula are:

For ends pivoted, or free to turn:

$$P = \frac{\pi^2 E I}{L^2} \left(\text{for } \frac{1}{r} \text{ more than about } 100 \right).$$

For one end pivoted and one free:

$$P = \frac{9}{4} \frac{\pi^2 E I}{L^2} \left(\text{for } \frac{1}{r} \text{ more than about } 150 \right).$$

For both ends fixed in direction:

$$P = \frac{4 \pi^2 E I}{L^2} \left(\text{for } \frac{1}{r} \text{ more than about } 200 \right)$$

A piston rod should be considered as fixed at one end and free to turn (slightly) at the other, for which condition the numerical coefficient is 9–4 instead of ¼. When ¼ is used it is no longer Euler's formula at all. The danger in Professor Barr's paper lies in his leading his reader to suppose that Euler's formulæ may be used in such cases with safety. For instance, suppose it be required to find the diameter of a piston rod 40 ins. long, carrying a compressive load of 40,000 lbs., with a factor of safety of 6. Now, if we consider the piston rod as fixed in direction at one end, as it surely is by means of the packing ring, and free to turn at the other, as suggested by Professor Barr, Euler's formula for this case gives:

$$6 P = \frac{9}{4} \frac{\pi^2 E I}{L^2} = \frac{9 \pi^2 E d^4}{4 \times 64 L^2}, \text{ whence we find } d = 1\tfrac{5}{8} \text{ ins.}$$

The area of this rod is 2 sq. ins., and hence the stress per sq. in. is 20,000 lbs. As the ultimate strength of a column is its elastic limit, which for a steel rod is about 40,000 lbs. per sq. in. we find we have in reality but a factor of safety of two instead of six as we have supposed.

J. B. Johnson.

Washington University, St. Louis, Mo., August 26th, 1897.

TEST OF NICKEL-STEEL ARMOR PLATE.

Vickers, Sons & Co., Limited, Sheffield, had a most successful trial at Shoeburyness of a nickel-steel Harveyed armor plate, 11 11-16 inches thick, measuring 10 feet by 7 feet, and backed with 12 inches of oak. The trial was to satisfy the conditions of the English Admiralty, viz.: That the plate should stand three shots from a 12-inch gun, two with a striking velocity of 1,850-foot seconds and the third with not less than 1,800-foot seconds without any part of the plate or projectile being driven completely through the wood backing or the plate in any way cracking seriously. The result obtained completely satisfied these requirements. The first shot had a striking velocity of 1,861-foot seconds, the projectile being broken to small pieces, and the penetration being only 2⅝ inches, with no cracks. The second shot gave a striking velocity of 1,868-foot seconds, with practically the same result, the penetration being 2¾ inches. It was then decided, as these two shots had been so successfully kept out, to fire the third shot with a velocity of 1,860-foot seconds, which was done with the same result as the first two rounds, the penetration being only 2½ inches. A 12-inch B. L. gun was used, firing Holtzer projectiles of 714 pounds. The plate was accepted as having completely fulfilled all the conditions required.—*Iron and Steel Trades Journal.*

SUDDEN COOLING OF NEARLY PURE IRON.

Professor Arnold, in discussing the influence of sudden cooling on nearly pure iron, attacks the allotropic theory of iron advanced by Professor Howe, and shows that the experiments on which it is based, admittedly erroneous to some extent, would not justify the conclusions drawn from them. This allotropic theory, briefly stated, claims that when nearly pure carbonless iron is heated to about 1,600 degrees F., it assumes an allotropic form possessing a tenacity far greater than ordinary iron, and this property is nearly all retained when the metal is suddenly quenched. Professor Arnold goes on to give the methods of Professor Howe for obtaining data on which he based his theory, and points out what he thinks is a weakness in the chain of reasoning. He finds that the break at a point in the curve of recalescence of a steel was not proved to be accompanied by a corresponding break in the curve based on the physical strength and the various quenching temperatures. This Professor Arnold considers the crucial test of the whole theory, and to examine the point he melts Swedish bar iron in a crucible, casts a 50-lb. ingot which was then hammered and rolled to a five-eighths inch round rod. From this the test-pieces were prepared. The material when analyzed had but 0.22 per cent. impurities, of which carbon was 0.07. The test-pieces had a cross section of 0.1 square inch, had both ends recessed, one for the reception of a thermo-couple of the Le Chatelier pyrometer, and the other for the introduction of the holding bar, which enabled the operator to rapidly quench the test-piece when the desired temperature was reached. All bars were heated to 1,800 degrees F., allowed to cool to the desired temperature, being then at once plunged into iced brine. The heating and cooling was conducted in an atmosphere of pure nitrogen, preventing all scaling of the metal, and leaving it almost as well polished after quenching as it was before heating. Tensile tests were now made and curves constructed which seemed to warrant the conclusion that "the increasing tenacity as the temperature of quenching runs up is a measure of crystalline stresses, internal and external. When these stresses are counterbalanced by the flow of metal preceding rupture, the mass resumes its normal ductility as measured by the reduction in area." Professor Arnold would then seem to conclude that there is nothing in the theory of an allotropic state of iron, but the phenomena observed are entirely of a nature compatible with a single state of existence of the element iron.—*Engineering*, July 9th.

WHY RAILS BREAK IN TRACK.

The American Engineer, Car-Builder, and Railroad Journal for September has an article on the above subject, which opens up with a discussion of the broken St. Neats rail on the Great Northern Railway in England. It states that the microscopic flaws found in this rail are occasionally met with in rails of both high and low carbon before they are put into service. It occurs to the reviewer that as many rails fail at once when used, possibly there is some connection, not yet made clear, between these cracks in new rails and their immediate failure. The article gives as the usual American practice a 0.45 carbon steel for light sections, and 0.55 to 0.65 for the heavy modern rail. The modern 0.60 carbon rail has an elastic limit of 55,000 to 65,000 lbs., an ultimate breaking strength of 125,000–130,000 lbs., per square inch, and an elongation on drop test of 14-18 per cent. The 0.45

carbon common rail has only 35,000–45,000 lbs. elastic limit, 80,000–110,000 lbs. ultimate, and 3-12 per cent. elongation on drop test. This drop-test elongation is obtained by the following method of testing: Rail butts, which would be scrap steel, anyhow, are placed on two rigid supports three feet apart (about two tie spaces) sometimes head up, sometimes side up, and equidistant punch marks are placed on the maximum flexion fibre. A weight is now allowed to drop freely from a 20-foot height, and the elongation noted. A number of data are given regarding this test, also Mr. Dudley's formula for the tensile strength likely to be developed in a rail of given composition. On the mechanical treatment of rails while making, the following is given: Cool rolling hardens the rail, hot rolling makes it soft and liable to warp while on the cooling bed, while blue cold rolling increases its strength and hardness, but puts it in bad wearing shape. The top of the rail should conform to the wearing surface of the tire, otherwise the metal will flow, and the head should not be too thick. The article calls attention to the desirability of a close inspection by a steel specialist, and afterward a continued lookout for dents in the flanges of the rail, which should be at once counteracted by placing a tie beneath the spot and spiking it well, as the rail is certain to give way there sooner or later. These dents are liable to occur at any time owing to carelessness in handling the rails while unloading or in spiking them down. The question of fatigue in rails and the modern tendency to rush the mills and thus make them produce inferior material is dwelt upon, also the effect of hammer blows on the part of the locomotive drivers, etc. Rail joints are spoken of, and Mr. Dudley's work commented upon. One statement would, however, appear incorrect to the reviewer, for when it is said that "because rails break from below upwards, therefore the microscopic cracks noted by Mr. Andrews probably have no bearing on the subject," it runs directly contrary to Mr. Stead's and Professor Ledebur's investigations which show that when a blow is directed upon the under side of a rail, the cracks in the upper face are the starting points of the break, and that therefore microscopic flaws, at least when on the surface of the rail head, seem to have everything to do with the subject. The article concludes with the following service demands for a good rail: The working stress shall not exceed one-fifth the elastic limit. It must be tough enough not to break with the flection incident to a poor track, and rigid enough to distribute all shocks or vibrations over several ties instead of one. Internal stresses due to cold rolling, unequal cooling, cold bending, or local heating should be absent. No dents, flaws, or signs of bad usage should be noticeable. Finally, eternal vigilance, the occasional record of the dynagraph car, and the plentiful use of brains in manufacturing the rails, as well as in inspecting and maintaining them, should be accorded.

MANUFACTURE OF BRICKS FROM BLAST FURNACE SLAG.

In a review of an article in *Stahl und Eisen* a method of making bricks from blast furnace slag is discussed. Slag containing much lime and only a little magnesia disintegrates to a fine powder when left to cool in the air. If, however, while in the melted state, it is subjected to the action of a stream of cold water, a hard sharp sand is obtained, which has an altogether different behavior. The process is carried out by quenching the slag as it leaves the blast furnace, special care being taken to let the stream run very broad and with an inclination which experience shows to be best. A stream of water is directed in such a manner that the sand formed may remain in scattered heaps. This material is now lifted out of the water by means of perforated baskets and sent to the brick-yard. Here it is mixed with the proper quantity of milk of lime and thoroughly stirred by machinery. The mixture is molded into bricks under some pressure and set to dry for eight days or so, according to the humidity of the atmosphere. About 1,000 of these bricks can be made an hour in this manner, and hardening is caused by the reaction between lime and the silica of the slag, in addition to the absorption of carbonic acid from the air. Dark slags are said to be inferior for brick making purposes, the lighter grades being preferred. They are said to require more lime than the light slags, must remain mixed up 24 hours longer before they can be molded properly, and finally cannot be transported for three months on account of the chemical reactions taking place more slowly in them.—*Dingler's Polytech. Journal,* July 16th.

HARDENED PLATES AND BROKEN PROJECTILES.

In this number of *Engineering,* Mons. L. Bertin completes his review of a series of tests with armor plates and hardened projectiles. M. Bertin takes the tables prepared by Mr. Ellis, which catalogue

108 projectiles fired against 30 Harveyized plates, and subjects them to a very critical analysis. He finds that of the 108 shots fired, 68 were such that their value, as far as penetration is concerned, could be calculated exactly. These results give the Harveyized plates an increase of over 50 per cent. above the resistance of the regular type of armor plate. Of these 68 shots, 49 resulted in broken projectiles, and the other 19 gave complete penetration. The author works out constants for the various conditions for application in his formula to obtain the required thickness of plates to resist projectiles, and finds that as the resistance of the material used increases, the decrease in thickness is more rapid than the increase of velocities of the projectiles. A series of very interesting tables is now given to cover this point, as well as to show the effects on hardened and on non-hardened plates. The actual striking effect is discussed and views of the perforations and broken projectiles given. The salient points to be recorded are the elastic deformation to which the plates become subjected, the plates being broken by the play of elasticity along the cracks, resulting in a perforation of less diameter than that of the projectile. Moreover the best plates are made of metals with a high elastic limit. The permanent local deformities produced are in the nature of a flow of the metal along the lines of least resistance. In soft plates therefore a portion of this flow goes outward from the front face. Harveyizing making a hard skin, the outward flow here is in the shape of splinters, and by the opposition of this hard skin, to the flow of the softer metal below, the resisting power of the plate is increased. The bulk of the metal pushed out goes by way of the rear side, and hence the hole is larger in diameter here than that of the projectile, something like in the punching of the rivet holes. The sudden stopping against an inflexible surface on the part of the projectile, compresses it violently, which may cause it to break. To distribute the pressure better a soft steel cap was proposed which allows the pressure to become applied over the whole projectile better and thus aid in its penetration. These soft caps act, so to speak, like lubricants between two hard metals in collision, and have been found uniformly successful where tried. The conclusions arrived at are that if projectiles are improved as rapidly as plates, additional security for vessels is to be looked for in a proper structural combination of horizontal with vertical Harveyized plates, and the coal bunkers, cellular subdivisions, etc., which renders blows of projectiles less dangerous than formerly, and allows less weight of armor.—*Engineering*, August 13th.

PROFESSOR FARADAY, Sir Humphry Davy's successor, made his first experiments in electricity by means of an old bottle while he was still a working bookbinder. And it is a curious fact that Faraday was first attracted to the study of chemistry by hearing one of Sir Humphry Davy's lectures on the subject at the Royal Institution. A gentleman, who was a member, calling one day at the shop where Faraday was employed in binding books, found him poring over the article "Electricity" in an Encyclopædia placed in his hands to bind. The gentleman, having made inquiries, found that the young bookbinder was curious about such subjects, and gave him an order of admission to the Royal Institution, where he attended a course of four lectures delivered by Sir Humphry. He took notes of them, which he showed to the lecturer, who acknowledged their scientific accuracy, and was surprised when informed of the humble position of the reporter. Faraday then expressed his desire to devote himself to the prosecution of chemical studies, from which Sir Humphry at first endeavored to dissuade him; but the young man persisting, he was at length taken into the Royal Institution as an assistant; and eventually the mantle of the brilliant apothecary's boy fell upon the shoulders of the equally brilliant bookbinder's apprentice.

Editor of DIGEST OF PHYSICAL TESTS.

DEAR SIR:—Not long ago I had occasion to test the strength of some leather belting, and not having the time to make jaws suitable, the pieces were cut as wide as could be held in the flat grip. A discussion arose as to the disadvantage under which the leather might be placed by not being able to adjust itself. It was affirmed that a piece 2 in. wide would not hold four times as much as a piece ½ in. wide. Tests were made and the averages showed that the smallest cross-section held more per square inch than the largest. Similar samples were then tested in properly constructed clamps, and while the results were similar the difference was not very marked.

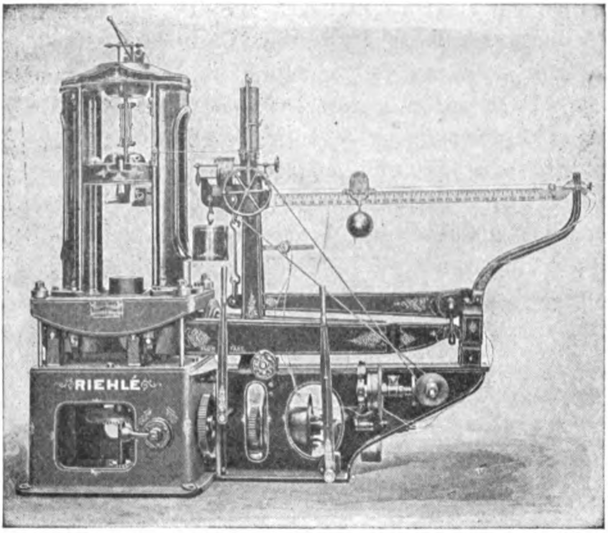
The highest tensile strength was observed in a small sample, and was 4,880 lbs. per square inch. The lowest was observed in the largest piece, and was 3,955 lbs. per square inch.

Of course like results might not again be obtained, although the samples were all taken from the same piece and as near together as possible. I simply note the result of the trials.

Yours truly, WALTER FLINT,
Professor of Mechanical Engineering,
Maine State College, Orono, Me.

Riehlé United States Standard Testing Machines

From 10 lbs. to 1,000,000 lbs. Capacity



(COPY.)

U. S. NAVY YARD,
WASHINGTON, D. C., July 13th, 1896.

RIEHLÉ BROS. TESTING MACHINE CO.,
1424 N. Ninth Street, Philadelphia, Pa., U. S. A.

Gentlemen :—In reply to yours of 10th inst. relative to the 100,000-lb. Testing Machine supplied by your firm, would say that the same is quite satisfactory, and is in constant use.

There is no objection to any persons, who are interested, visiting the yard and witnessing the performance of the Machine.

Yours truly,
(Signed) CHAS. O'NEIL,
Commander U. S. Navy, Supt. N. G. Factory.

N. B.—This is a Riehlé U. S. Standard 100,000 lbs. Automatic and Autographic Vertical Screw Power Testing Machine, with Screw Beam, viz., "Washington," Plate 333.

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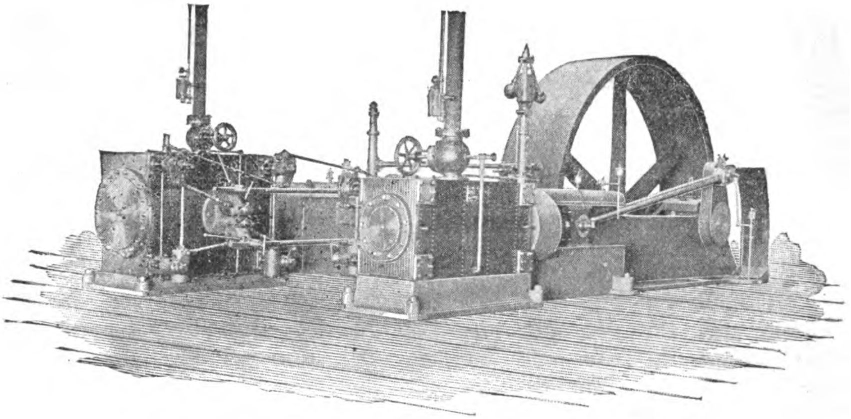

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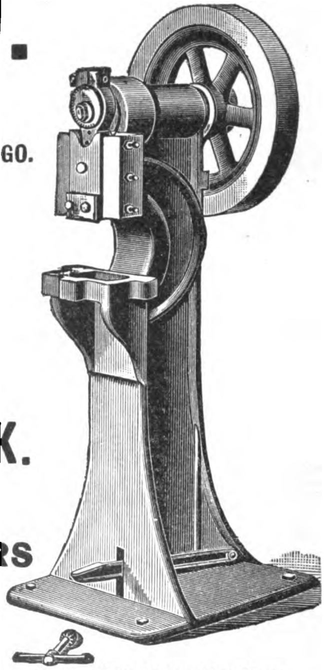

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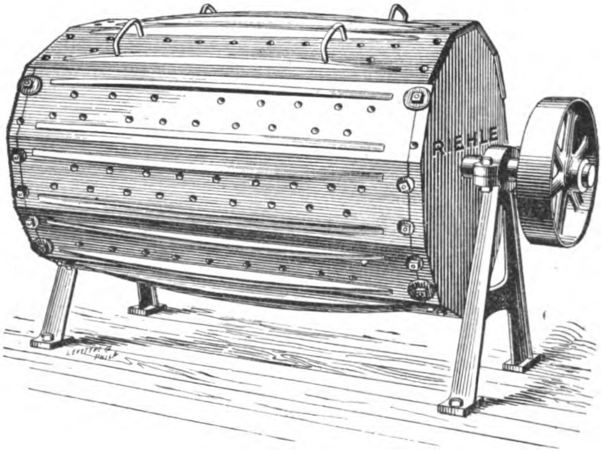

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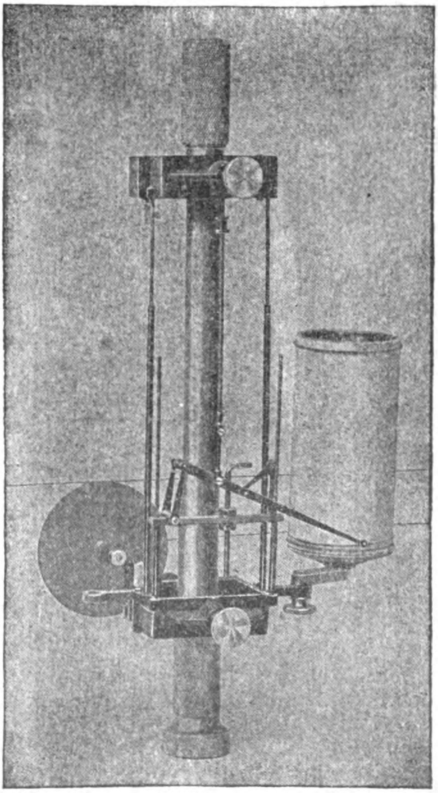

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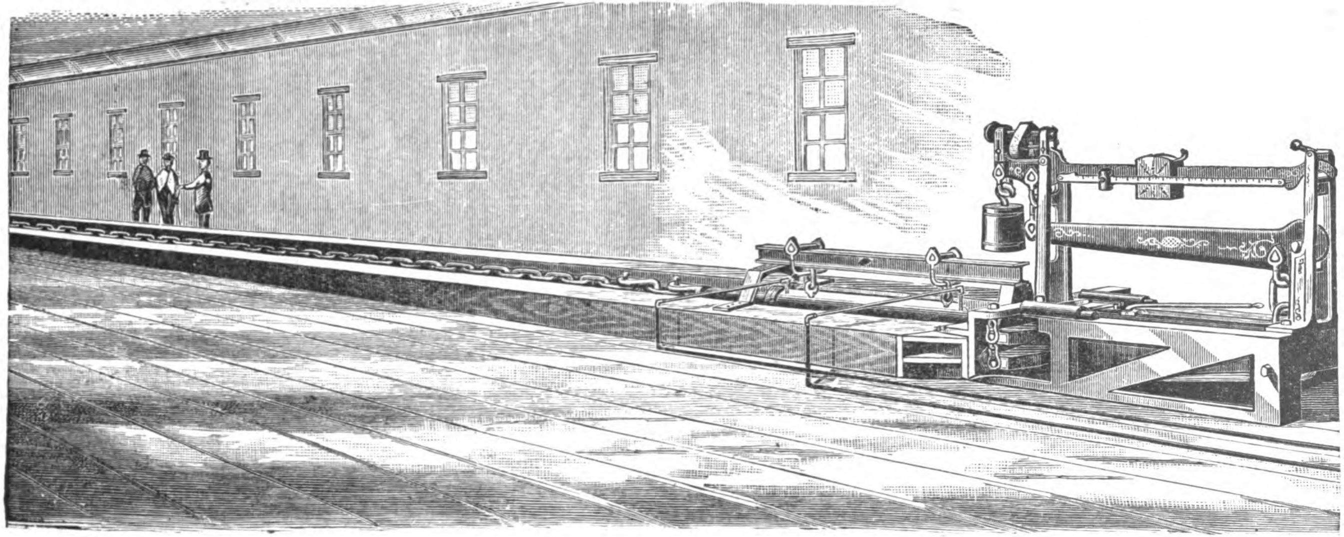

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